Yakima River Basin Integrated Water Resource Management Plan

Economic Analyses of the Proposed Keechelus Reservoir-to-Kachess Reservoir Conveyance

Consistent with the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*

FINAL DRAFT

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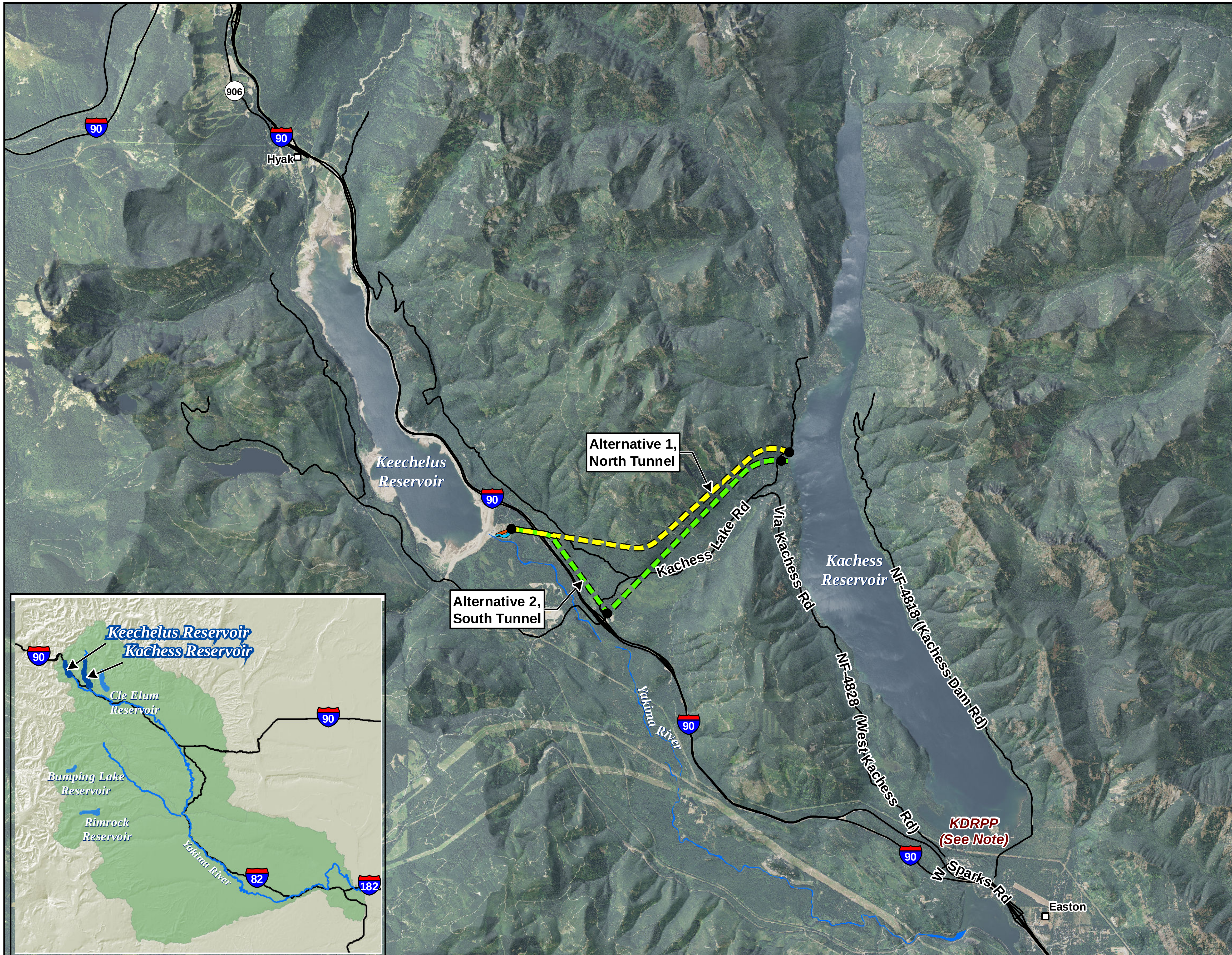

Keechelus-to-Kachess Conveyance

Legend

- Major Road
- Portal
- Alternative 1 (North Tunnel Alignment)
- Alternative 2 (South Tunnel Alignment)
- Conveyance Option A
- Conveyance Option B

RECLAMATION
Managing Water in the West

DEPARTMENT OF ECOLOGY
State of Washington

N W E S

0 7,000
Feet

0 1.25
Miles

Note: General location of the Kachess Drought Relief Pumping Plant (KDRPP). The KDRPP is a separate but related project currently in the feasibility design phase.

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List of Terms and Acronyms

BTE	Bull trout enhancement
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EQ	Environmental Quality account
IMPLAN®	IMpact Analysis for PLANning modeling software
Integrated Plan	Yakima Basin Integrated Water Resource Management Plan
KDRPP	Kachess Drought Relief Pumping Plant
KKC	Keechelus-to-Kachess Conveyance
MCR	Mid-Columbia River (steelhead)
NED	National Economic Development account
NPV	Net present value
OMR&P	operation, maintenance, replacement, and power
OSE	Other Social Effects account
Principles and Guidelines	1983 Federal *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*
Reclamation	Bureau of Reclamation
RED	Regional Economic Development account
YakRW	Reclamation's RiverWare® model for the Yakima River basin

1.0 Introduction and Summary

This report evaluates one component of the Yakima River basin Integrated Water Resource Management Plan (Integrated Plan): the Keechelus-to-Kachess Conveyance (KKC). The U.S. Department of Interior Bureau of Reclamation (Reclamation) and Washington State Department of Ecology (Ecology) are partners in this project. The goals of the Integrated Plan are as follows: to protect, mitigate, and enhance fish and wildlife habitat; to provide increased operational flexibility to manage instream flows to meet ecological objectives; and to improve the reliability of the water supply for irrigation, municipal supply, and domestic uses (Reclamation and Ecology, 2012a). Figure 1 shows the location of the KKC as well as the separate but related Kachess Drought Relief Pumping Plant (KDRPP).

Reclamation and Ecology would implement Bull Trout Enhancement (BTE) as an element of the KKC in Kachess and Keechelus reservoirs, as well as elsewhere in the Yakima River basin, to help meet the goals of the Integrated Plan. Therefore, this report includes information on BTE.

1.1 Project Overview

The KKC would convey water from Keechelus Reservoir to Kachess Reservoir to reduce flows in the upper Yakima River, thereby improving rearing habitat for steelhead and spring Chinook, and improving the ability to refill Kachess Reservoir following drought years. The proposed conveyance tunnel would extend east from the Yakima River near the Keechelus Dam outlet and would discharge on the west shore of Kachess Reservoir. The tunnel would be 12-foot diameter and approximately 4-to-5 miles long, depending on the alternative selected.

Reclamation would operate the KKC, diverting water by gravity flow from the Yakima River downstream of Keechelus Reservoir into the tunnel to Kachess Reservoir. Reclamation would transfer flows in all years when Keechelus Reservoir is above its target pool elevation and Kachess Reservoir is below target pool elevation.

Reclamation and Ecology are evaluating two alternatives:

1. North Tunnel Alignment
2. South Tunnel Alignment

See the *Keechelus-to-Kachess Conveyance Feasibility Design Report* (Reclamation and Ecology, 2015b) for more details.

Although this technical memorandum focuses on the KKC, it also discusses the KDRPP because of important interactions between the two projects that affect the economic outcomes of the KKC. The KDRPP would involve construction of an outlet on the Kachess Reservoir about 80 feet lower than the current outlet, and a pump station, which together would provide access to an additional 200,000 acre-feet of water during droughts. The KKC would help fill Kachess after a drought year, and in other years would keep Kachess Reservoir at a higher elevation than under existing conditions.

Reclamation and Ecology 2014 describes BTE. The two agencies would implement the entire BTE program with either the KKC alone, KDRPP alone, or KKC and KDRPP together. Bull trout are federally listed as threatened. BTE would address a need for improving the resiliency of bull trout populations in the Keechelus and Kachess watersheds. BTE combined with the KKC, or with the KDRPP, or both, would provide a net positive benefit to bull trout populations in the Yakima River basin.

1.2 Relationship of the KKC to the Full Integrated Plan

The Integrated Plan is a comprehensive approach to managing water resources and ecosystem restoration improvements, responding to recurring droughts in the Yakima River basin and the risk of climate change. Reclamation and Ecology developed the Integrated Plan in 2011 in collaboration with the Yakama Nation, irrigation districts, environmental groups, other Federal agencies, the State of Washington, and local governments. The Integrated Plan addresses seven elements: reservoir fish passage, structural and operational changes to existing facilities, surface water storage, groundwater storage, habitat/watershed protection and enhancement, enhanced water conservation, and market reallocation. As a whole, the Integrated Plan would benefit fish and irrigation and offer a synergy that would otherwise be unattainable without the plan.

Reclamation and Ecology estimate the total cost for implementing the Integrated Plan at $3 to $5 billion (plus annual operation and maintenance costs estimated at $10 million), and anticipates its implementation over 30 years.

Reclamation and Ecology would implement the Integrated Plan in phases, using a balanced approach. A balanced approach means that during each phase, Reclamation and Ecology would advance activities representing the full spectrum of Integrated Plan components (e.g., storage, fish passage, water conservation, habitat restoration, etc.). Concurrent implementation of balanced elements is needed in order to achieve the full and synergistic benefits of the Integrated Plan for ecosystem improvement and water supply

In March 2014, Reclamation and Ecology identified an Initial Development Phase, covering the first ten-year period (2013-2023). It would advance all seven plan elements and would represent approximately one-quarter of the estimated plan cost (about $900 million). The Initial Development Phase would include implementation of Cle Elum Fish Passage, Cle Elum Pool Raise, Kachess Drought Relief Pumping Plant, and Keechelus-to-Kachess Conveyance; and components associated with each element of the Integrated Plan, such as habitat restoration, agricultural conservation, and groundwater recharge. The Initial Development Phase would also supplement a $99 million acquisition of watershed lands under the Integrated Plan, executed in 2013 by the State of Washington in the Teanaway River subbasin (the Teanaway River flows into the Yakima River).

Reclamation and Ecology recognize that if the Integrated Plan is separated into pieces, economic analysis of the pieces would not result in all components showing positive benefit-to-cost ratios by themselves. However, the Federal *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (*Principles and Guidelines*) (Water Resources Council, 1983) indicate that components should be analyzed individually. That is the purpose of this report.

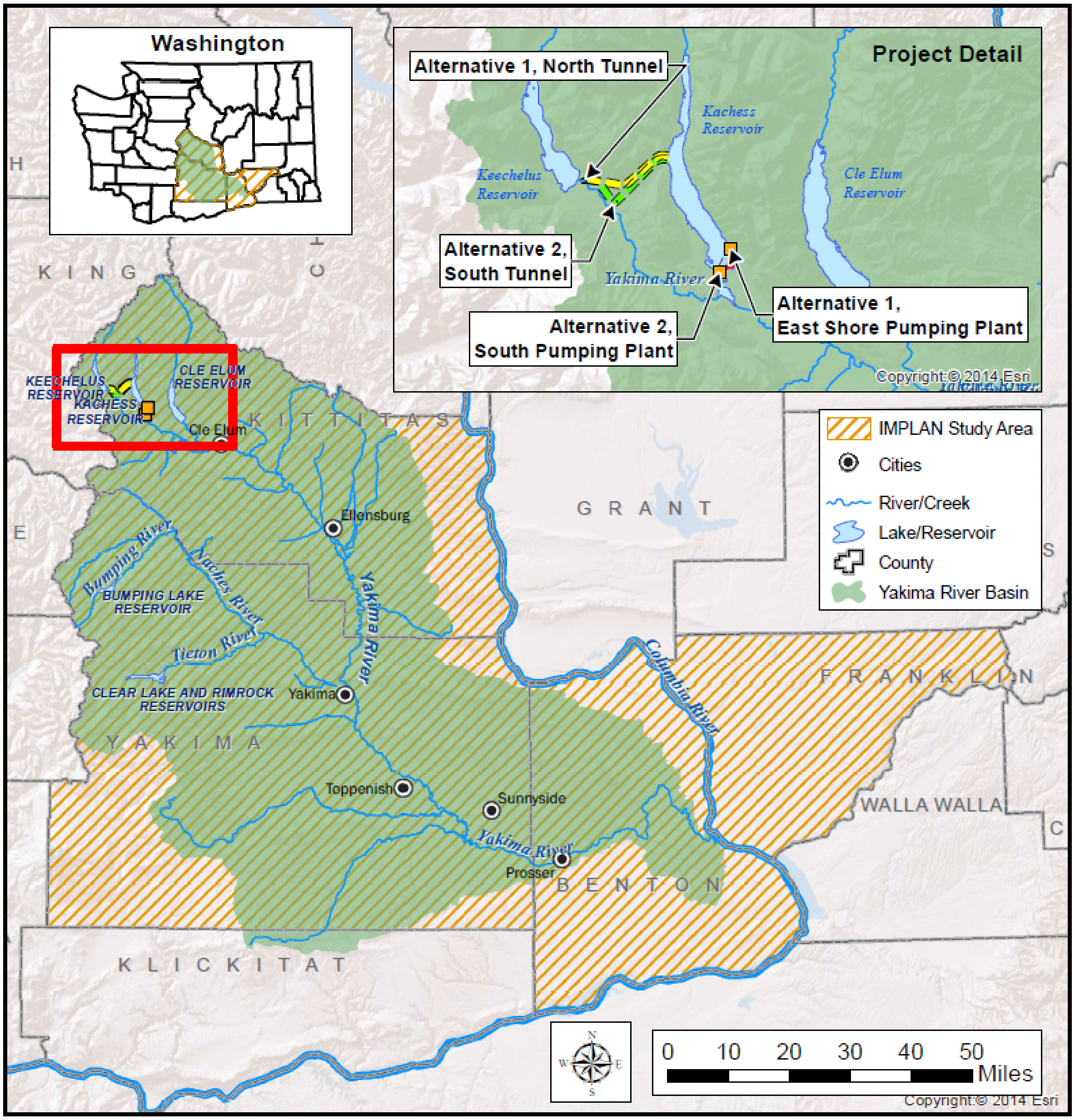
Reclamation and Ecology issued a Four Accounts analysis of the Integrated Plan at full build out (30-year costs) in 2012. That report tabulated the combined benefits and costs of the full suite of Integrated Plan projects and programs. Analyzed as a whole, the Integrated Plan yields a highly favorable benefit-to-cost ratio ranging from 1.4 to 3.2. The costs of the KKC represent approximately 7 percent of the total cost of the Integrated Plan. The quantified benefits of the KKC represent slightly less than 1 percent of the total quantified benefits of the Integrated Plan if the KKC is implemented by itself; or slightly less than 2 percent if the KKC is implemented together with the KDRPP.

1.3 Methodology Overview

This economic analysis uses the "Four Accounts" framework specified in the *Principles and Guidelines* (Water Resources Council, 1983).[1] The four accounts are National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). This report builds on the Four Accounts analysis of the entire Integrated Plan, completed in October 2012 (Reclamation and Ecology, 2012b). That analysis described the economic effects of the Integrated Plan in the aggregate. It did not assess the effects of specific projects included in the Integrated Plan. For the current NED and RED analysis, ECONorthwest applied the economic models and data developed for the overall plan to the fullest extent appropriate for the individual project analyses, using updated information on the projects and adjustment to 2014 dollars.

A team that included staff from Reclamation and Ecology and environmental firms consulting to the agencies conducted the EQ and OSE evaluations. All members of the team had worked on the KDRPP and KKC Draft Environmental Impact Statement (EIS) (Reclamation and Ecology, 2015b) and have expertise in environmental analysis, engineering, and Yakima Project operations. The agencies held a workshop to develop the EQ and OSE evaluations. Participants applied their subject area expertise, experience, and knowledge of the project and project area in their evaluations. All decisions made during the workshops used group consensus. Reclamation and Ecology reviewed the evaluation with technical experts from Federal and State resource agencies, the Yakama Nation, and Yakima River basin irrigation districts to receive additional input on the evaluations.

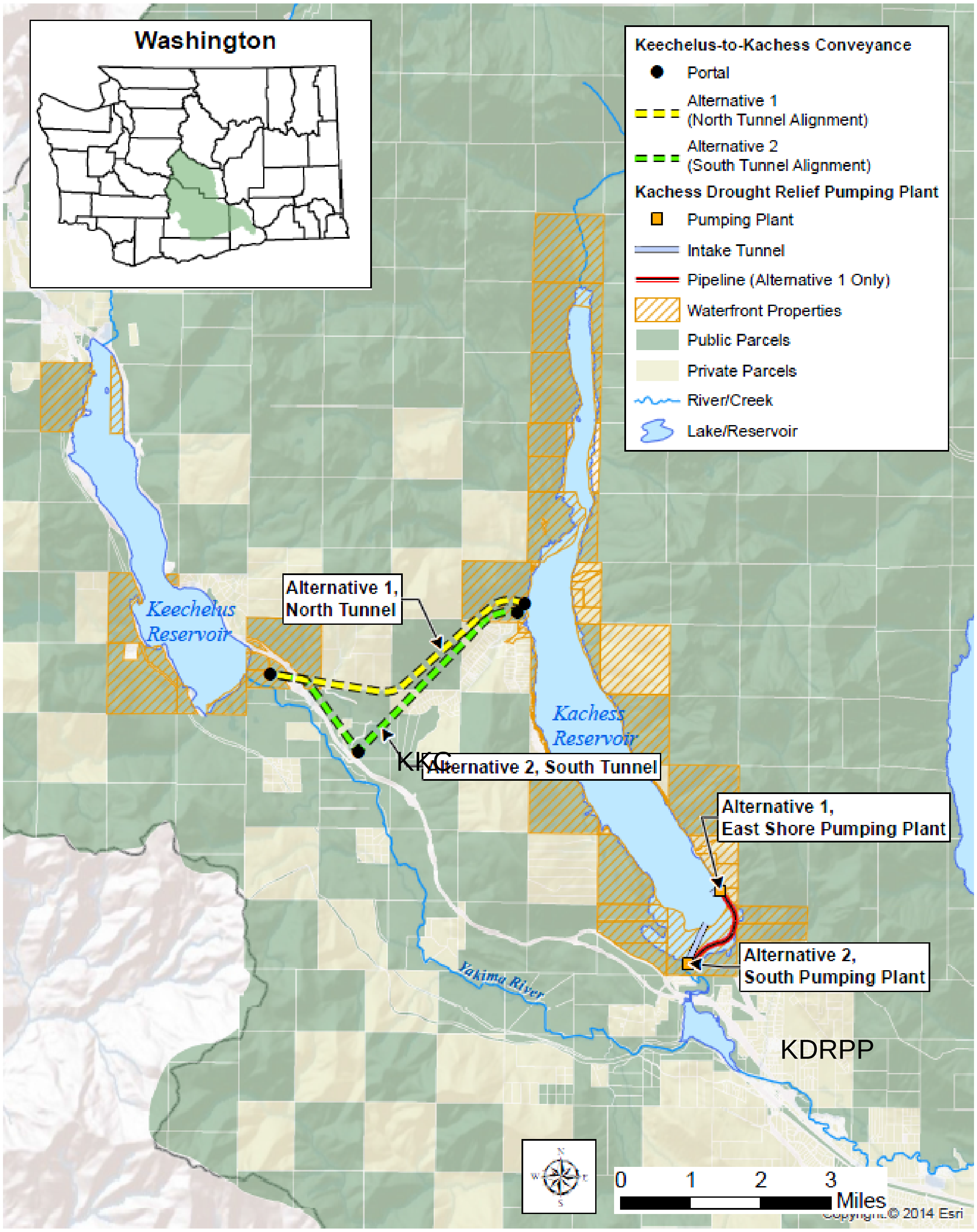
[1] Although the Council on Environmental Quality updated the *Principles and Guidelines* in 2013, these updates will not take effect until agency-specific guidelines are prepared and accepted. For the U.S. Department of the Interior, this will start in June 2015.



Source: ECONorthwest

Note: IMPLAN® study area includes the entire counties indicated (including area underlying watershed boundary).

Figure 1. Overview of Integrated Plan Elements and Location of the KDRPP and KKC Projects



Source: ECONorthwest. Locations are approximate.

Figure 2. Land Ownership Surrounding the KDRPP and KKC Projects

1.4 Summary of NED Findings

The KKC would provide instream flow improvements for the Keechelus Reach of the Yakima River, which benefit Chinook salmon and steelhead. The improvement in salmon and steelhead populations would be worth an estimated $18 to $54 million over 40 years[2] to Washington residents. This would increase to $29 to $86 million when including Oregon residents as well.

The NED analysis considers the KKC in the context of the KDRPP implementation for cases when the joint effect is greater than the sum of the individual effects. When combined with the KDRPP, the KKC would increase agricultural benefits compared to the KDRPP alone. The KKC would increase water availability to prorationed water users under drought conditions. These benefits, via increased net farm earnings, would be worth an estimated $34 million in discounted net present value (NPV) over 100 years, and would increase to $117 million under future, adverse climate change conditions. In the municipal water supply category, the KKC would provide slight additional incremental benefits if combined with the KDRPP.

Table 1 shows estimated 100-year costs and benefits for the KKC in discounted, NPV terms (costs are reported as negative values, to contrast with benefits). The present value costs are $258 million for the North Tunnel Alternative and $291 million for the South Tunnel Alternative. Costs include construction, interest during construction, operations, maintenance, power, and replacement costs. Benefits of the KKC range from $29 million to $204 million. Benefits at the low end of the range represent the KKC alone, without considering the effects of climate change. Benefits at the high end of the range represent the incremental effect of the KKC if constructed with the KDRPP, with effects of climate change considered. In all cases shown, costs exceed benefits, leading to negative net present values. As noted previously, this was expected. The KKC contributes to overall purposes of the Integrated Plan and the Initial Development Phase, both of which have favorable benefit-to-cost ratios.

The cost of BTE is $7 million to $13 million. Benefits of BTE have not been quantified.

The values shown in Table 1 do not include additional, unquantified costs and benefits. These are listed in Table 2.

[2] The fish benefit estimates are limited to a timeframe of 40 years rather than the full 100 year period of analysis because of constraints of the model and data supporting these calculation.

Table 1. Present Values of the KKC and BTE Over 100 Years

	KKC Alone	Incremental Effects of KKC when combined with KDRPP
Salmon and Steelhead Benefits[1]	$29 to $86 million	$29 to $86 million
Agriculture Water Supply Benefits[2]	$0 to $10 million	$34 to $117 million
Municipal Water Supply Benefits[2]	0	$0.2 to 0.5 million
KKC Benefit Subtotal	*$29 to $96 million*	*$63 to $203 million*
North Tunnel Alternative Costs	-$258 million	-$258 million
South Tunnel Alternative Costs	-$291 million	-$291 million
KKC Cost Subtotal	*-$258 to -$291 million*	*-$258 to -$291 million*
Net Present Value, North Tunnel	-$229 to -$162 million	-$195 to -$55 million
Net Present Value, South Tunnel	-$262 to -$195 million	-$228 to -$88 million
BTE Benefits	Not quantified	Not quantified
BTE Costs	-$6.7 to -13.3 million	-$6.7 to -13.3 million

Note: Values discounted at 3.375% per year. In the cost category, only long-term operations, maintenance, replacement and power costs are discounted. The initial investment costs (field costs, interest during construction, and non-contract costs) are not discounted. All benefits are discounted as they would accrue after construction is completed.
[1] Range based on range in number of salmon and steelhead, from minimum estimate to maximum estimate.
[2] Range based on effects without climate change to effects with climate change.

Table 2. Unquantified Benefits and Costs of the KKC

Unquantified Benefits	Unquantified Costs
As an element of the overall Integrated Plan, the KKC is expected to reduce conflict over management of water resources and fisheries in the Yakima River basin, reduce potential for litigation and improve certainty for stakeholders. Increased flexibility of Yakima Project operations may provide undefined benefits for fisheries and water supply, and greater opportunities to employ market-based transactions to allocate water among uses. If the KDRPP is constructed, the KKC would accelerate refill of Kachess Reservoir in years following drawdown. This will help to reduce the KDRPP impacts on bull trout, recreational uses of Kachess Reservoir, and aesthetic qualities of Kachess Reservoir. The agencies would implement BTE only if the KKC or the KDRPP were implemented. The BTE would provide benefits to listed bull trout by improving access to reservoir tributaries for spawning, improving nutrient availability, and improving genetic diversity. The benefit-transfer method used to estimate the economic value of improved fisheries is limited to the first forty years of benefits. If the public continues to value the improved fisheries after that, then additional benefits would accrue to the projects.	Travel restrictions, noise, and other construction impacts on local residents and users of Kachess Reservoir Road, during the three-year construction period for the KKC.

Readers should consider the results shown in Table 1 and Table 2 in the context of the full Integrated Plan, and more particularly the Initial Development Phase. Table 3 shows the estimated costs and benefits of the Initial Development Phase as a whole. Even without all of the benefits quantified, the overall benefits of this phase substantially outweigh the overall costs.

Table 3. Net Present Value Benefits and Costs of Initial Development Phase

Project	Costs	Benefits
Cle Elum Fish Passage	$130M[1]	$1,300M to 1,900M
KDRPP	$437M to $446M	$215 to $317M
KKC (incremental with KDRPP)	$$258M to $291M	$63 to $203M
Bull Trout Enhancement	$13M	Not quantified
Cle Elum Pool Raise	$18M	Not quantified
Habitat Projects	$85M	Not quantified
Water Conservation Projects	$70M	Not quantified

[1] Costs of Cle Elum Fish Passage and Cle Elum Pool Raise are not discounted.

1.5 Summary of RED Findings

The estimated economic impacts of construction of the KKC North Tunnel Alternative would be 1,094 job-years within the four-county local region and 1,780 job-years for the State of Washington as a whole. This includes $60 million in personal income for the four-county region and $92 million at the State level. The estimated corresponding job-years for the South Tunnel Alternative would be 1,223 job-years in the four-county region and 2,001 job-years for the State as a whole. Personal income under the South Tunnel Alternative construction would be an estimated $67 million in the four-county region and $103 million for the State as a whole. The KKC would also generate three additional job-years annually through the life of the project.

The BTE program would generate an estimated 59 job-years in the four-county region and 98 job-years for the State as a whole. It would also generate an estimated $3.2 million locally in personal income and $5 million for the State as a whole.

Table 4 summarizes the economic impacts of the KKC in the four-county region. Increases in agricultural activity provided by the KKC in conjunction with the KDRPP would generate 212 local job-years during drought years over the 100-year timeframe, under historical water supply conditions, and this increases to 340 job-years per drought year under adverse climate change. There are also an additional 10 job-years in the rest of Washington under historical water supply conditions, and 16 job-years under adverse climate change.

The total economic output increase under historical climate conditions for the four-county region would be an estimated $28 million, and it would be $46 million under adverse climate change conditions.

Table 4. Economic Impacts of the KKC in the Four-County Region

	Construction	Average annual
North Tunnel Alternative		
Output	$165 million	$43,400
Personal Income	$60 million	$13,900
Job Years	1,094	0.3
South Tunnel Alternative		
Output	$186 million	$43,400
Personal Income	$67 million	$13,900
Job Years	1,223	0.3
Bull Trout Enhancement Plan		
Output	$9 million	N/A
Personal Income	$3.2 million	N/A
Job Years	59	N/A
Agriculture - Increase of KKC & KDRPP over KDRPP		
Output		$28-$46 million
Personal Income		$7-$12 million
Job Years		212-340
Total		
Output	$174-$195 million	$28-$46 million
Personal Income	$63-70 million	$7-$12 million
Job Years	1,154-1,283	212-340

Note: Construction impacts are for the full, multi-year construction periods (undiscounted) while average annual values are for one average year over the full timeframe.

1.6 Summary of EQ Findings

Results from the EQ analysis suggest that under the No Action Alternative, conditions for most EQ resources would stay the same or decline. This is especially true for instream flows.

Implementation of the KKC would produce a moderate positive impact on instream flows and bull trout. The KKC would produce moderate positive impacts on fish abundance, including middle-Columbia-River steelhead. The KKC would provide minor positive impacts to adaptability to climate change. Other EQ resources would experience minor negative impacts under the KKC. The KKC would produce significant negative construction impacts during the construction period.

1.7 Summary of OSE Findings

Results from the OSE analysis suggest that the No Action Alternative would have moderate negative impacts on long-term productivity.

The KKC alternatives would produce minor negative effects from construction worker impacts and minor to moderate benefits to long-term productivity. The KKC would have minor negative urban and community impacts.

2.0 Methodology

The Federal *Principles and Guidelines* include the following definition of the Federal objective: "to contribute to national economic development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements" (Water Resources Council, 1983). The *Principles and Guidelines* establish four main accounts for organizing, displaying, and analyzing project alternatives: NED, RED, EQ, and OSE. NED measures the benefits and costs to the Nation, rather than to the region directly addressed by the Integrated Plan. NED benefits are increases in the total value of the national output of goods and services expressed in monetary units. They include increases in the net value of those goods and services that are marketed and those that are not be marketed. NED costs are the opportunity costs of resources used in implementing the Integrated Plan. Opportunity costs could reflect decreases in output or employment losses resulting from the Integrated Plan.

The NED analysis reported here for the Integrated Plan describes three categories of economic benefits: increases in fish populations, improvements in municipal and domestic water supply, and increases in the reliability of irrigation water during severe drought years. The computation of the different categories of benefits used analytical methods consistent with the *Principles and Guidelines*.

The RED analysis addresses market impacts due to project construction and operation, BTE construction, and agriculture production attributable to improved water supply reliability. RED focuses on local changes in the quality and quantity of goods and services in terms of market production, employment, and income.

New, agency-specific guidelines are currently being prepared based on the Water Resources Development Act of 2007 (Section 2031) updates. The Federal objective specifies that Federal water resources investments shall reflect national priorities, encourage economic development, and protect the environment by the following methods:

- Seeking to maximize sustainable economic development
- Seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used
- Protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems

These Federal objectives, when considered in the context of the complex water management challenges addressed by the Integrated Plan and the competing demands for limited Federal resources, mean that Federal investments in water resources should strive to maximize the net public benefits resulting from them. The 1983 *Principles and Guidelines* do not reference the concept of public benefits, but the new *Principles and Guidelines* references them. Reclamation has offered this explanation of the public benefits from water-related investments in the Mid-Pacific Region with regard to economic analyses of Shasta Lake management:

> *Public benefits encompass environmental, economic, and social goals, include monetary and non-monetary effects and allow for the inclusion of quantified*

> *and non-quantified measures. …. [I]n addition to traditional, monetized economic development, projects that contribute to Federal ecosystem and species restoration goals are relevant components of water project planning and development. Economic evaluation provides a way to understand and evaluate trade-offs that must be made between alternatives with respect to objectives, investments, and other social goals. It also provides a means to identify the plan that is acceptable, effective, efficient, and complete, and contributes the most favorably to national priorities.* (Reclamation, 2011)

2.1 NED Methodology

The NED account displays changes in the economic value of the national output of goods and services attributable to the individual project. The Federal objective is to contribute to national economic development consistent with protecting the Nation's environment. The NED account measures the beneficial and adverse monetary effects of projects and actions in terms of changes in the value of the national output of goods and services. It includes value estimates for project benefits and costs.

2.1.1 Overview of Federal Guidance

The definition of beneficial effects in the NED account includes increases in three categories: (1) the economic value of the national output of goods and services from a plan; (2) the value of output resulting from external economies caused by a plan; and (3) the value associated with the use of otherwise unemployed or under-employed labor resources.

Adverse effects in the NED account are the opportunity costs of resources used in implementing a plan. These adverse effects include implementation outlays, associated costs, and other direct costs.

The NED analysis includes the following set of basic assumptions:

- Installation period (the number of years required for installation)
- Installation expenditures (cost incurred for each year of installation)
- Period of analysis (lifespan or time horizon of the project over which benefits and costs occur, which includes installation and a period of time sufficient to capture significant beneficial or adverse effects, not to exceed 100 years)
- Benefit stream (the pattern of benefits that materialize over the period of analysis, calculated in average annual equivalent terms)
- Operation, maintenance, and replacement costs (the pattern of costs that materialize over the period of analysis necessary to maintain the stream of benefits)
- Discount rate (the rate at which both benefits and costs are adjusted)

The following sections describe the analysis assumptions.

2.1.2 Assumptions for the NED Analysis

Analytical Approach. The directions outlined in Chapter II of the *Principles and Guidelines* provide methods to estimate each type of benefit and cost included in the KKC economic analyses. The quantitative analyses focus on benefits and costs expected to arise from significant project effects. This report analyzes the KKC relative to a baseline scenario without the KKC. In addition, it also analyzes the KKC under adverse climate change conditions (Reclamation and Ecology, 2015a). Where relevant, the analyses also consider the KKC in the context of the KDRPP implementation when the joint effect is greater than the sum of the individual effects.

Installation Period and Installation Expenditures. The NED analysis tailored the installation period to the construction period for each project component and alternative, as detailed in the design information developed by HDR in the feasibility design studies (e.g. HDR, 2014b). Expenditures come from the feasibility design study field cost estimates and noncontract costs. See Section 3.0 for more detailed information by project.

Period of NED Analysis. The NED analysis considers all projects and effects within a 100-year timeframe that begins when project benefits begin to occur. For the KKC, this period begins in the year following completion of construction. Therefore, construction costs occur prior to the 100-year project timeframe.

Benefit Stream. Benefits include improved net farm earnings that are possible because of increased irrigation water supply, avoided groundwater pumping costs for municipal water supply, and instream fish benefits. Fish populations are based on the public's willingness-to-pay for improvements in salmon and steelhead populations in the Columbia River Basin, as described in the 2012 Four Accounts analysis (Reclamation and Ecology, 2012b). See Sections 3.2.1 and 3.2.2 for a discussion of the specific categories of benefits evaluated for each project and alternative.

Operation, Maintenance, and Replacement Costs. The proposed projects include operation and maintenance costs for the full timeframe, as well as scheduled capital replacement costs based on equipment lifespans. See Sections 3.2.3 and 3.2.4 for a discussion of the specific categories of costs evaluated for each project alternative.

Discount Rate. The NED analysis incorporates a discount rate of 3.375 percent where appropriate, which is the applicable rate that Federal agencies use in the formulation and evaluation of water and related land resources plans in fiscal year 2015, from October 1, 2014 to September 30, 2015 (Reclamation, 2014). Discounting of costs and benefits begins in the first year of the 100-year period of analysis, which for the KKC is the first year after completion of construction.

2.1.3 Challenges and Solutions to Address Independent Project Effects

To quantify the benefits and costs of the KKC consistent with the guidelines and assumptions outlined above for the NED, one must be able to describe the effects of each project separately from the total effects of the seven program elements and related projects and actions that are part of the Integrated Plan. The Integrated Plan, by definition, is an integrated system, with individual projects and actions operating together to produce synergistic effects to achieve the overall goals and objectives of the plan. For example, the water supply benefits provided by the combination of the KKC and KDRPP are greater than the two projects modeled alone and summed. Consequently, in practice, it is unlikely that Reclamation and Ecology would undertake individual projects without all or at least a subset of the complete system designed to yield a spectrum of benefits. Any analysis of an individual element of the plan in isolation requires careful consideration of several factors:

- Is the project capable of producing effects in isolation, or is the stream of benefits (and costs) dependent on other project elements?
- Is the analysis likely to underestimate or overestimate the full value of any of the effects when analyzed in isolation?
- Is the analysis, when added to independent assessments of other project elements, likely to double-count or exclude specific benefits or costs?

Due to these concerns and requirements for individual project analysis, the analyses in this report do not include any water quantity trading benefits attributable to project alternatives. There is a baseline level of trading in this NED analysis under drought conditions identical to that described and applied during the 2012 Four Accounts analysis. However, this report has no benefits of trading attributed to individual project alternatives (same level of trading under baseline and all alternative permutations). Whereas the 2012 Four Accounts analysis considered the whole of the Integrated Plan without any breakdown by individual components, this NED analysis does break out the individual effects of the KKC and KDRPP projects. Similarly, there are no water conservation benefits under the Integrated Plan attributed to these project alternatives, although there are water conservation effects on water availability and prorationing incorporated into the baseline water supply.

Water quantity trading is an important part of the Integrated Plan's ability to increase water reliability in the Yakima River basin. The NED analysis attributed none of that benefit to specific structural projects, but the connectivity, flexibility, redundancy, and insurance the structural network provides is crucial to the physical, operational, and behavioral requirements necessary to support increased trading and the overall efficiency gains that it provides. Trading provides an important share of the overall benefit for water reliability, as described in the 2012 Four Accounts analysis. To the extent the KKC contributes to this functionality of water trading, these benefits are unquantified, and contribute to an underestimate of the benefits.

There are differences in values of increased water reliability in this analysis compared to the 2012 Four Accounts analysis for a number of reasons. The 2012 Four Accounts analysis used a period of record from 1981 to 2005. A longer period of record used in the current analysis goes from 1926 to 2009. It includes a wider range of water-supply conditions compared with the shorter period of record. Reclamation used the extended period of record because using a longer period of record is generally considered good practice in the field of hydrologic modeling. However, due to climate change considerations, the longer period of record used in this study is not necessarily more representative of current or future conditions, compared with the shorter period of record used previously.

This analysis also expands upon the modeling conducted for agriculture benefits in the Four Accounts analysis, to account for varying levels of drought severity in addition to drought frequency. Section 3.2.1 contains more detail on this approach.

2.2 RED Methodology

The Regional Economic Development (RED) account registers changes in the distribution of regional economic activity that result from each project. Evaluations of regional effects use nationally consistent projections of income, employment, output, and population. This account evaluates the beneficial and adverse impacts of projects and actions on the economy of the affected region, with particular emphasis on income and employment measures. The affected region reflects the geographic area where Reclamation and Ecology expect significant impacts to occur. Both monetary and nonmonetary terms can be measures of impacts.

2.2.1 Overview of Federal Guidance

The account uses two measures of the effects of the plan on regional economies: regional income and regional employment.

- **Regional Output:** The value of goods and services produced is the broadest measure of economic activity. Regional output is the sum of expenditures, employee income, proprietor income, profits, and taxes.
- **Regional Income:** The positive effects of a plan on a region's income are equal to the sum of the NED benefits that accrue to that region, plus transfers of income to the region from outside the region.
- **Regional Employment:** The positive effects of a plan on regional employment are directly parallel to the positive effects on regional income, so that the organization of the analysis of regional employment effects is in the same categories, using the same conceptual bases as the analysis of positive regional income effects.

The regions used for RED analysis are those regions within which the plan would have particularly significant income and employment effects, described below.

2.2.2 Assumptions for the RED Analysis

Analytical Approach. The RED analysis applies IMPLAN® (IMpact Analysis for PLANning) modeling software to examine the economic impacts of the Integrated Plan across the region. IMPLAN® is an input-output model that utilizes local industry-level data and traces spending associated with a specific project as it moves through the defined impact area. The RED analysis uses IMPLAN® default conditions and other regional economic data to represent the baseline conditions. ECONorthwest used the most-current available IMPLAN® data (2012) in the RED analysis.

Regional Definition. The Yakima River basin defines the region for the analysis. As was done for the 2012 RED analysis of the Integrated Plan, ECONorthwest uses the counties of the Yakima River basin (Kittitas, Yakima, and Benton) and Franklin County, which incorporates the entire Kennewick-Richland-Pasco metropolitan area into the analysis (Figure 1). ECONorthwest also identified economic impacts that would occur for the State of Washington as a whole. Although effects associated with implementing these projects would occur outside these counties, for the purposes of the RED analysis, this area adequately captures the regional effects of implementing the projects.

Categories of Impacts. The analysis incorporates the following categories of impacts:

- Spending associated with construction
- Spending associated with operation, maintenance, replacement, and power
- Changes in the value of agricultural production of the alternatives (differences in gross farm earnings)

Accounting for Local Contributions. RED impacts only capture those that are not paid for by local contributions. In other words, these impacts do not include the local money that is simply transferred from one group to another within the defined region. Reclamation and Ecology assume that, for the KKC, local contributions would pay 25 percent of capital and local sources would pay 100 percent of operating expenses.

Although effects analyzed in the NED analysis may result in changes in the value of other goods and services that could affect the level of income and employment in the region (e.g., changes in recreation and property values), existing data are insufficient to include them in the RED modeling using IMPLAN®. ECONorthwest also analyzed spending associated with construction, operation, and maintenance of BTE Plan projects and presented those results separately.

2.2.3 Challenges and Solutions to Address Independent Project Impacts

As described above for the NED analysis, the challenge of identifying and attributing effects to the KDRPP and KKC projects separately arises because the design of these two projects is to work together to generate the intended effect. However, this issue is less likely to confound the RED analysis.

The impacts on RED largely stem from spending on construction and operation and maintenance. The cost data are available separately for the two projects and their alternatives, and sufficiently detailed to support the IMPLAN® modeling process. The costs of each project are not dependent on each other or other major cost factors, such as implementation of the Integrated Plan. Thus, the IMPLAN® modeling process addresses the KDRPP and KKC separately, and if both projects are completed, the costs and impacts would sum linearly. The impacts of agricultural production, however, do involve consideration of the KKC in tandem with the KDRPP.

The IMPLAN® analysis of spending stemming from changes in the value of agricultural production mirrors the relevant scenarios used to examine the effect in the NED analysis.

2.3 EQ and OSE Methodology

A team that included staff from Reclamation, Ecology, and environmental consultants to the agencies conducted the EQ and OSE evaluations. All members of the team had worked on the KDRPP and KKC Draft EIS (Reclamation and Ecology, 2015b) and have expertise in environmental analysis, engineering, and Yakima Project operations. The EQ and OSE evaluations were conducted in a workshop format. Participants applied their subject area expertise, experience, and knowledge of the project and project area in their evaluations. All decisions made during the workshops used group consensus.

The Reclamation and Ecology team met to conduct the initial EQ and OSE evaluation on February 4, 2015. Reclamation and Ecology reviewed the evaluation with technical experts from Federal and Washington State resource agencies, the Yakama Nation, and Yakima River basin irrigation districts to receive additional input on the evaluations.

The Reclamation and Ecology team considered the input of the technical experts; revised resource categories, subcategories, weighting, and scoring; and made final decisions on the EQ and OSE evaluations.

The process used during the EQ and OSE workshops involved five major steps:

1. Identifying the environmental resource categories from the Draft EIS that were most important for decision making
2. Prioritizing the resource categories
3. Dividing some resource categories into subcategories to better capture the benefits and impacts of the alternative
4. Weighting the EQ and OSE categories or subcategories
5. Scoring the benefits and impacts of the EQ and OSE categories or subcategories

2.3.1 Overview of Federal Guidance

The *Principles and Guidelines* include criteria for evaluating alternatives based on the EQ and OSE accounts to display the effects of the alternatives. The *Principles and Guidelines* define these accounts as follows:

- **The EQ account** displays nonmonetary effects on significant natural and cultural resources. This account displays the effects on ecological, cultural, and aesthetic attributes of significant natural and cultural resources that cannot be adequately measured in monetary terms within the NED and RED accounts.
- **The OSE account** registers plan effects from perspectives that are relevant to the planning process, but not reflected in the other three accounts.

2.3.2 Assumptions for the EQ Analysis

Table 5 lists the EQ resource categories selected by the team along with a brief explanation of the resource categories. The Reclamation and Ecology team included the resource categories that (1) have the most effect on the purpose and need for the KKC, and (2) the KKC would potentially most impact. The following are the objectives of the KKC identified in the Draft EIS (Reclamation and Ecology, 2015b):

- Capture excess runoff from the Keechelus watershed.
- Improve capabilities for refilling Kachess Reservoir during and following dry and drought years.
- Reduce high flows from Keechelus Dam in the upper Yakima River during the irrigation season to improve rearing habitat for steelhead and spring Chinook upstream of Lake Easton.
- Implement the BTE package of aquatic habitat enhancements, and accomplish assessments of current conditions and limiting factors for bull trout populations in the Yakima River basin to improve the effectiveness of future enhancement actions.

The team divided some resource categories into subcategories to allow for more refined evaluation of the benefits and impacts. Table 5 includes these subcategories.

The Draft EIS evaluated other resources, but Reclamation and Ecology did not include them in the EQ evaluation because the evaluation focuses on resources that are most important for decision making. The agencies did not include vegetation and wetlands in the EQ evaluation because they are committed to mitigating impacts to ensure no net loss to wetlands or vegetation.

Table 5. KKC EQ Resource Categories

EQ Resource Category	EQ Resource Subcategories	Background
Surface water	Water supply	Improved water supply is part of the purpose and need for the KKC. As used here, water supply includes the benefits that would occur from improved water supplies that have not been monetized in the NED or RED, such as benefits of a more stabilized economy. Instream flows are included to represent the benefits other than those to fish that accrue from improved streamflows, such as improved water quality, aesthetics, etc.
	Instream flows	
Bull trout	Food-based prey	Enhancements to bull trout habitat is part of the purpose and need for the KKC. This category includes the subcategories of food-based prey, habitat, and passage, which are key indicators of improvements to the productivity and function of aquatic habitat conditions for bull trout.
	Habitat	
	Passage	
Fish	Fish abundance	Fish habitat improvements are part of the purpose and need for the KKC. This resource category includes anadromous and resident fish that are not listed as threatened or endangered under the Endangered Species Act. Fish abundance accounts for overall improvements in fish populations, health, and distribution that will occur under the plan. Fish passage refers to ecosystem benefits of providing fish with access to more habitat.
	Fish passage	
Surface water quality	Reservoir water quality	Import of water from Keechelus Reservoir could introduce contaminants to Kachess Reservoir.
Wildlife	Wildlife habitat	Construction could disrupt wildlife species in the area and the proposed action could improve wildlife habitat in some areas.
Other threatened and endangered species	Northern spotted owl	The northern spotted owl and MCR steelhead are federally listed species that the project could affect.
	MCR steelhead	
Recreation	Changed character of recreation	The BTE habitat improvements could change the character of recreation at Gold and Cold creeks.
Land use	Property/easement acquisition	The project will require acquisition of some real property or easements.
Cultural Resources	Cultural and archaeological resources	Construction of the KKC facilities and BTE habitat improvements at Gold and Cold creeks could disturb cultural resources. Improved habitat from reduced flows in the Keechelus Reach could improve subsistence resources.
	Subsistence resources	
Climate Change	Adaptability to climate change	The KKC is included in the Integrated Plan as a project to help meet the Integrated Plan's purpose of anticipating climate change and increasing Reclamation's flexibility in responding to those changes.
Construction Impacts	Construction impacts	Construction could cause temporary impacts such as increased emissions, fugitive dust, noise, and vibration. Construction vehicles could increase traffic on local roads and Interstate 90.
	Transportation	

MCR= Mid-Columbia River (steelhead).

The team prioritized the 11 resource categories based on how the resource categories affected the purpose and need. They rated three resource categories that most directly affect the purpose and need as being of primary priority -- surface water, fish, and bull trout. (Note that bull trout are not included in the fish resource category since they are listed as threatened under the Endangered Species Act). They rated other categories as being of secondary priority. The team weighted water resources, fish, and bull trout higher than the secondary priority resources. All resource categories were assigned weights based on their priority and so that the weights totaled to 1.0. Table 6 shows those weights.

The team then weighted the EQ subcategories. Similar to the prioritization process, the team assigned weights to subcategories based on the participants' estimation of how the subcategories would meet the purpose and need of the KKC and potential impacts on the resources. Within each category, the subcategory weights total to 1.0. The team then multiplied category weights by the subcategory weights to obtain the final weights for the EQ resources. Table 6 presents the weights of the categories and subcategories.

Table 6. EQ Categories and Rankings

Category	Category Weight	Sub-categories	Subcategory Weight	Final Weight
Surface water	0.2	Water Supply	0.5	0.1
		Instream Flows	0.5	0.1
Bull trout	0.2	Food-based prey	0.33	0.067
		Habitat	0.33	0.067
		Passage	0.33	0.067
Fish	0.2	Fish abundance	0.5	0.1
		Fish passage	0.5	0.1
Surface water quality	0.05	Reservoir water quality	1.0	0.05
Wildlife	0.05	Wildlife	1.0	0.05
Other threatened and endangered species	0.05	Northern spotted owl	0.5	0.025
		MCR steelhead	0.5	0.025
Recreation	0.05	Changed character of recreation	1.0	0.05
Land use	0.05	Property or easement acquisition	1.0	0.05
Cultural resources	0.05	Cultural and archaeological resources	1.0	0.05
Climate change	0.05	Adaptability to climate change	1.0	0.05
Construction impacts	0.05	Construction impacts	0.5	0.025
		Transportation	0.5	0.025
TOTALS	1.0			1.0

MCR= Mid-Columbia River (steelhead).

2.3.3 OSE Assumptions for the Analysis

The team also identified and prioritized the OSE account. As noted above, the OSE account includes perspectives that are not included in the NED, RED, or EQ accounts. The team identified two resource categories to include in the OSE account -- urban and community, and long-term productivity. The urban and community category includes impacts to local communities caused by large numbers of construction workers. Long-term productivity includes the subcategories of improved fish populations and resilience to climate change. These subcategories capture the social benefits of improved fish populations and resilience to climate change. OSE accounts often include environmental justice, but the team decided not to include that category because the KDRPP and KKC Draft EIS did not identify any potential environmental justice impacts (Reclamation and Ecology, 2015b). Table 7 lists and describes the OSE categories.

Table 7. OSE Resource Categories

OSE Resource Category	OSE Resource Subcategories	Background
Urban and community	Construction worker impacts	This category is included to capture the impacts that would occur in communities surrounding the construction area from the large number of construction workers employed on the project. These impacts include housing demand.
Long-term productivity	Improved fish populations	Long-term productivity includes the nonmonetary and social benefits that accrue from the project. Sub categories include improved fish populations and resilience to climate change.
	Resilience to climate change	

Table 8 shows the OSE categories and subcategories weights along with the final weights assigned to each. The team weighted long-term productivity higher than urban and community because of the overall potential to influence social conditions, such as improved fish populations and resilience to climate change, in the Yakima River basin.

Table 8. OSE Categories and Rankings

Category	Category Weight	Sub-categories	Subcategory Weight	Final Weight
Urban and community	0.2	Construction worker impacts	1.0	0.2
Long-term productivity	0.8	Improved fish populations	0.5	0.4
		Resilience to climate change	0.5	0.4
Totals	1.0			1.0

2.3.4 EQ and OSE Impact Rating

After the team identified, ranked, and weighted the EQ and OSE resource categories, the team rated the impacts. The EQ and OSE evaluations compared the impacts of the No Action Alternative and the two action alternatives (KKC North Tunnel Alignment and KKC South Tunnel Alignment) as described in the Draft EIS (Reclamation and Ecology, 2015b). The team rated the impacts by comparing the impacts of the No Action Alternative and the two action alternatives to the existing baseline conditions.

During the rating process, the Reclamation and Ecology team rated the No Action Alternative based on current Yakima Project operations and the projects and actions identified to occur under the No Action Alternative --Yakima River Basin Water Enhancement Project Phase II conservation projects, and the Washington State Department of Transportation Interstate 90 Snoqualmie Pass East Phase 2A project. For all alternatives, the team considered impacts and benefits over a 50-year period. The team also considered potential impacts of climate change, changes in vegetation and wildlife, and anticipated development that would occur in the next 50 years for both alternatives.

To compare the effects of the alternatives, the team developed a scale that accounts for both positive and negative impacts. The scale, listed below, also includes a zero rating to indicate no change relative to existing conditions.

0 = no change from existing conditions

3 = major positive impact	-3 = major negative impact
2 = moderate positive impact	-2 = moderate negative impact
1 = minor positive impact	-1 = minor negative impact

The team rated the impacts using the same consensus-based approach as the rankings. To determine the final scores for the EQ and OSE evaluations, the team multiplied the resource category scores for each alternative by the category or subcategory weight. The resulting numbers reflect both the potential significance of the effect and the relative importance of the resource category or subcategory.

3.0 KKC Analyses and Findings

This section focuses on the categories of effects and impacts that would be associated with the KKC project. It begins with a basic description of the KKC project, and then describes analyses and results.

3.1 KKC Project and Alternatives

The KKC project would improve management of summer flows in the Yakima River between Keechelus Dam and Lake Easton, to improve summer rearing habitat for salmon and steelhead. It would improve Reclamation's ability to refill Kachess Reservoir following drought years. The KKC would also increase overall storage and supply flexibility in the

Yakima River basin by providing a means to transfer water from Keechelus Reservoir to Kachess Reservoir.

3.1.1 KKC Alternatives

The proposed conveyance extends east from the Yakima River just downstream from the Keechelus Dam outlet and discharges on the west shore of Kachess Reservoir. The tunnel would be 12 feet in diameter and approximately 4.1 to 4.9 plus miles long, depending on the alternative selected. It would have a design capacity of 400 cubic feet per second.

Reclamation would operate the KKC by diverting water by gravity flow from the Yakima River downstream of Keechelus Reservoir. Reclamation would transfer flows to Kachess Reservoir in all years when Keechelus Reservoir is above its target pool elevation and Kachess Reservoir is below target pool elevation.

Reclamation and Ecology are evaluating two alternatives:

1. North Tunnel Alignment
2. South Tunnel Alignment

See the KKC *Feasibility Design Report* for more details on the alignment options and engineering details (Reclamation and Ecology, 2015c).

3.1.2 Bull Trout Enhancement

Reclamation and Ecology expect BTE to provide long-term net benefits to the bull trout populations in the Keechelus and Kachess Reservoirs. Populations in both watersheds are listed under the Endangered Species Act and are some of the smallest populations in the Yakima River basin. Reestablished year-round tributary passage (Gold Creek, Cold Creek, and potentially upper Kachess River) into the reservoirs is expected to increase the number of spawners and redds deposited that otherwise would be precluded from spawning that year. The team expects this to cause increased population productivity and abundance.

Artificial nutrient enrichment of these watersheds is also included in the BTE plan. Artificial nutrient enrichment is expected to most directly increase juvenile abundance and provide an improvement in the prey base for sub-adult and adult bull trout residing in the reservoirs. This would also cause an increase in growth, condition factors, and survival rates, which over time would result in an increase in population abundance and productivity. In addition, artificial nutrient enrichment would support the future reintroduction of sockeye into these two reservoirs. If proven feasible, there is the potential to expand the amount of spawning and juvenile rearing habitat in Box Canyon Creek above the falls by approximately 3 miles, to increase population abundance for the Box Canyon population. Reestablished passage into Cold Creek from the Keechelus Reservoir would open up approximately 2.2 miles of habitat that is currently inaccessible.

The implementation of BTE has the potential to accelerate the rate of population recovery greatly in terms of abundance and increased genetic diversity for the Keechelus and Kachess populations by translocation of fish from healthier populations in the Yakima River basin.

Reclamation expects these collective actions to increase bull trout abundance, productivity, and genetic diversity for the Keechelus and Kachess populations. Because of these actions, these populations should become more resilient to the natural fluctuation in environmental factors that can negatively impact population abundance and productivity. These actions would also provide a benefit to the overall health of the ecosystem.

This analysis assumes that if either the KKC or KDRPP are implemented alone, the full BTE costs will be assigned to that project. If both are implemented, half of the BTE costs are assigned to each.

3.2 NED Analysis

3.2.1 Quantified Benefits

Water Supply for Agriculture

Mechanism of the Effect. The KKC would potentially provide agriculture water supply benefits by increasing water availability for proratable users during drought conditions. Proratable users have junior water rights that are satisfied by an equal share among all proratable users, after senior, nonproratable users have received their full allotment (Reclamation and Ecology, 2011). Hydrologic modeling demonstrates how the KKC alone changes available water for proratable users under drought conditions. The KKC can also provide benefits by making the KDRPP more valuable than it would be alone in terms of available water under drought conditions.

Irrigated agriculture is the largest user of water in the Yakima River basin. The Yakima Irrigation Project (Yakima Project), operated by Reclamation, provides most of the water used for irrigation. The Yakima Project provides water to six irrigation divisions: Roza Irrigation District (Roza), Kittitas Reclamation District (Kittitas), Sunnyside Valley Irrigation District (Sunnyside), Wapato Division (Wapato), Yakima-Tieton Irrigation District (Tieton), and Kennewick Irrigation District (Kennewick). The first five in this list would be the most directly affected by the Integrated Plan. They have 81 percent (1,938,300 acre-feet) of the total, proratable and nonproratable, entitlements (2,406,917 acre-feet) to water in the Yakima, Tieton, and Naches Rivers above the Parker gage (Reclamation and Ecology, 2011).

The amount of land irrigated in the Yakima River basin is limited. Federal law constrains the amount of land served by the Yakima Project, and the available water supply limits the amount of land irrigated outside the Yakima Project. The Yakima Project currently supports irrigation for 383,000 acres (Reclamation and Ecology, 2011). Because of the constraints on irrigated acreage, the Integrated Plan assumes that acreage that is currently available for irrigated agriculture in the basin would not expand in the future. Furthermore, the plan aims to improve reliability of irrigation water supplies, but not to bring about an expansion of irrigated acreage.

The reliability of water supplies for irrigators served by the Yakima Project differs considerably for two groups of irrigators: nonproratable and proratable. Nonproratable water rights are more senior and have priority dates before May 10, 1905. The total water supply available serves these rights first, which Reclamation defines each year based on reservoir storage, runoff forecast, and return flow estimates. Proratable water rights, however, have a priority date of May 10, 1905. When the total water supply available cannot fully serve both groups, it goes first to satisfy the nonproratable water rights insofar as possible, with any remainder shared by the proratable water rights. In each of the droughts occurring in recent decades, Reclamation has been able to supply nonproratable water rights fully, but proratable water rights have received reduced (prorated) supplies, as low as 37 percent of normal supply in 2001. The Integrated Plan aims to improve the reliability of supplies for irrigation users with proratable water rights.

The Parker gage measures flow in the Yakima River, downstream of the city of Union Gap. Reclamation and Ecology use this gage as a key control point for water resources in the Yakima River basin. The primary concern about water-supply reliability involves the five irrigation districts above the Parker gage: Roza, Kittitas, Sunnyside, Wapato, and Tieton. The analysis does not include Kennewick Irrigation District because it typically does not experience reduced water availability during a severe drought that affects other districts.

To facilitate the presentation, the following discussion refers to each of these entities as a district. The focus narrows further to Roza, Kittitas, and Wapato Districts because Sunnyside and Tieton have stated they do not need additional water during drought periods even though portions of their entitlements are proratable (Reclamation and Ecology, 2011). Table 9 compares the proratable water rights for the three districts with the rest of the Yakima Project entitlements above the Parker gage. Kittitas, Roza, and Wapato Districts hold 82 percent of the total proratable water rights above the Parker gage. They hold 96 percent of the proratable water rights above the Parker gage, exclusive of Sunnyside and Tieton Districts.

Table 9. Proratable Water Rights above Parker Gage

Irrigation Districts	Proratable Entitlements (Acre-Feet)	Percent of Total Proratable Entitlements	
		Total	Not Including Sunnyside and Tieton
Roza	393,000	30	35
Wapato	350,000	27	31
Kittitas	336,000	26	30
Subtotal	*1,079,000*	82	96
Sunnyside	157,776	12	0
Tieton	30,425	2	0
Subtotal	*1,267,201*	97	96
Nondistrict Entitlements	42,874	3	4
Total	1,310,075	100	100

Source: Adapted from Reclamation and Ecology, 2011

Method of Quantification. The basis of increased water supply value for agriculture is the change in the value of net farm earnings among receiving irrigation districts. Under drought conditions, proratable water users must fallow a portion of their fields. The analysis utilizes a model of farming activity and revenue to compare net farm earnings among the irrigation districts at various levels of prorationing. Reclamation developed this model for the 2012 Integrated Plan analysis to quantify the effect by considering the difference in production and earnings due to water availability for each alternative scenario and the relevant baseline scenario(s).

Description of Model. Reclamation's RiverWare® model for the Yakima River basin, known as "YakRW," produced hydrologic modeling results for a number of scenarios, including (1) the baseline No Action Alternative, (2) the KKC alone, (3) the KDRPP alone, and (4) the KKC and KDRPP. In addition, it generated versions of these scenarios under adverse climate change conditions, involving more frequent and more severe droughts. This model produces annual shares of water available to proratable users for each scenario, which serves as an input to the economic modeling of agricultural production and value.

ECONorthwest used the agricultural earnings model developed for the 2012 Integrated Plan analysis to quantify the economic effects. ECONorthwest updated prices and costs from the 2012 model using the most current data available, and adjusted figures to 2014 dollars. The model computes the direct increase in net farm earnings for irrigators in the Yakima Project who would receive improved reliability of water supplies because of the project.

The model addresses variable cost considerations from the farm budget perspective. It includes crop-specific annual variable costs per acre, annual crop-specific yield per acre, and crop prices. See the data section below for these sources. These parameters are consistent with the *Principles and Guidelines* (Section 2.3.5) regarding farm budget analysis.

During an average non-drought year, the model assumes irrigators have all the water they require to satisfy crop irrigation requirements. During drought years, the model assumes historical constraints on proratable water users and the baseline (pre-Integrated Plan) volume of water quantity trading among irrigators. The basis of trading is the reallocation of water from low-value crops to high-value crops, where the measurement of value is annual net farm earnings per acre-foot. The model assumes that accompanying financial transactions take place so that all parties are better than without trading. The model does not track individual acre-feet of water or individual transactions, but rather identifies equilibrium conditions, given constraints. Trading is constrained to a maximum of 30,000 acre-feet of water annually based on discussion with irrigation district representatives for the 2012 Four Accounts analysis, and only intradistrict trading is allowable for Wapato and Tieton, as suggested by district input. ECONorthwest established these assumptions to represent a baseline for the level and type of trading occurring without the Integrated Plan.

This section describes the data ECONorthwest used in the model. The model has three adjustable variables, and three output variables.

Adjustable Variables. Listed below are the model's three adjustable variables:

1. The degree of the constraint on water supply during a severe drought year (percentage of full entitlement available to proratable irrigators) based upon outputs of the YakRW model.
2. The minimum annual net farm earnings (dollars per acre-foot) for water buyers. This applies to crops receiving water through market-based water reallocation, recognizing that irrigators are unlikely to purchase water during a severe drought to irrigate low-value crops. It is set at $150 for these analyses based on consultations with the irrigation districts (Reclamation and Ecology, 2012b).
3. The maximum volume of interdistrict trading for Roza, Kittitas, and Sunnyside Districts (percent of available water that districts allow traded outside the district). This variable recognizes and avoids the potential adverse impacts on the districts' operations that can occur if trades disrupt normal operating procedures and

characteristics through substantial exports. It is set at 90 percent for these analyses, based upon consultations with the irrigation districts.

For the analyses in this memo, there is no change in allowable quantity of trading among alternatives, including the baseline No Action Alternative.

Output Variables. The model's three output variables include (1) annual net farm earnings, (2) volume of intradistrict trading, and (3) volume of interdistrict trading. The model produces these output variables, at the district level, for each scenario. It also generates crop-specific information by district identifying the predicted, or representative, composition of crop production under a particular scenario.

Description of Data. The spreadsheet model relies on three types of data: (1) data describing the crops grown in the five irrigation districts and the amount of water needed to satisfy each crop's irrigation requirements, (2) proratable and nonproratable entitlements across the five districts, and (3) annual net farm earnings, by crop, across the five districts. The following sections describe each type of data.

Crops and Water Demand. Table 10 identifies the crops used in the model, their distribution across the five districts, and water demand (by crop) in each district. The values in Table 10 rely on data from district-level surveys and the Washington State Department of Agriculture, collected over the past decade, and represent the most recent data available. For the 2012 Integrated Plan, ECONorthwest and other analysis team members communicated with the irrigation districts and other relevant agencies to identify any potential updates to the data. In all cases, no district or agency had any updated data for use in the analysis. The model assumes irrigators in each district continue using the same amount of land to produce the same mix of crops every year, and that water demand (in terms of acre-feet per acre, by crop) remains constant into the future. For example, the model assumes that apples grow on 548 acres in the Kittitas Reclamation District and that production requires 5.6 acre-feet of water per acre, both now and in the future.

Table 10. Crops and Water Demand by District

Crop	Kittitas		Roza		Sunnyside		Tieton		Wapato	
	Acres	Acre-feet/Acre	Acres	Acre-feet/Acre	Acres	Acre-feet/Acre	Acres	Acre-feet/Acre	Acres	Acre-feet/Acre
Alfalfa Hay	1,778	4.8	2,878	4.7	12,219	4.8	124	3.1	12,939	5.6
Apples	548	5.6	23,969	5.6	6,720	5.8	17,288	3.7	10,445	7.0
Asparagus	-	-	635	4.2	2,657	4.4	-	-	1,831	5.2
Concord Grapes	-	-	11,913	3.3	20,784	3.8	-	-	4,954	4.7
Hops	-	-	3,540	3.4	10,955	3.7	-	-	15,350	4.3
Mint	-	-	137	4.9	1,770	5.1	-	-	9,424	6.1
Miscellaneous	81	4.7	3,613	3.9	21,050	4.0	355	3.3	24,017	5.0
Other Grain	1,963	4.6	2,670	3.0	3,246	3.2	21	2.1	662	4.0
Other Hay	4,971	5.5	431	4.8	3,719	5.0	1,058	3.2	3,204	6.2
Other Tree Crops	256	5.3	8,797	5.5	9,534	5.8	2,729	3.6	3,211	6.7
Other Vegetables	6	4.1	270	2.5	525	3.0	-	-	3,286	4.1
Pasture	13,129	4.5	62	3.8	1,141	3.7	-	-	1,960	4.8
Potatoes	89	4.3	72	4.2	-	-	-	-	1,161	5.1
Sweet Corn	1,368	3.1	173	3.1	39	2.8	-	-	912	3.3
Timothy Hay	29,607	5.6	-	-	-	-	-	-	126	6.4
Wheat	1,710	4.4	1,333	3.0	2,892	3.2	-	-	15,621	4.0
Wine Grapes	10	3.1	11,998	3.3	1,992	3.8	9	2.1	12	4.7
Total	55,516	N/A	72,491	N/A	99,243	N/A	21,584	N/A	109,115	N/A

Source: Adapted from Washington State Department of Agriculture, 2010; Reclamation and Ecology, 2011.

Entitlements. The team used existing data describing water entitlements (in terms of acre-feet) to estimate the percentage of each district's water supply that is proratable and the percentage that is nonproratable (Reclamation and Ecology, 2011). The team applied these percentages (proratable and nonproratable) to crop acres in each district to distinguish entitlements by crop type. If, for example, 70 percent of a district's water entitlements are proratable, the analysis assumes that 70 percent of the water allotted for each crop in that district is proratable.

Annual Net Farm Earnings. Table 11 summarizes the data used in the model to derive annual net farm earnings. For each crop, the model uses average yield (Scott et al., 2004; Vano et al., 2009), price (U.S. Department of Agriculture, National Agricultural Statistics Service, 2013a, 2013b), and variable cost values (Washington State University Extension, various years; Reclamation, 2008) relevant to the five districts. The model calculated annual net farm earnings per acre by multiplying average yield by average price (to get annual gross farm earnings), then subtracting annual variable cost. There are insufficient data to distinguish between annual net farm earnings associated with different crops grown in different districts, so the model used the same values across the five districts. The model adjusted values to 2014 dollars using the commodity-specific producer price index from the U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2014).

Annual net farm earnings ($/acre) from Table 11 were divided by water demand (acre-feet/acre) for each crop in each district (from Table 10) to calculate irrigation-related annual net farm earnings ($/acre-foot).

Table 12 summarizes these values.

Table 11. Annual Net Farm Earnings ($/Acre) by Crop

Crop	Output Units	Average Yield (Units/Acre)	Average Price ($/Unit)	Annual Variable Cost ($/Acre)	Annual Net Farm Earnings ($/Acre)
Alfalfa Hay	Tons	5.6	$233	$608	$688
Apples	Tons	16.1	$505	$6,248	$1,859
Asparagus	Cwt	37.2	$92	$2,643	$775
Concord Grapes	Tons	8.6	$275	$602	$1,767
Hops	Pounds	1,976.2	$3	$3,356	$2,726
Mint	Pounds	124.9	$22	$2,084	$615
Miscellaneous	Bushels	200.0	$5	$530	$533
Other Grain	Bushels	141.5	$5	$530	$146
Other Hay	Tons	4.7	$206	$788	$180
Other Tree Crops	Tons	13.6	$1,273	$7,658	$9,660
Other Vegetables	Cwt	500.0	$19	$1,487	$8,008
Pasture	Tons	4.7	$233	$608	$487
Potatoes	Cwt	546.1	$7	$2,107	$1,947
Sweet Corn	Cwt	193.9	$5	$457	$605
Timothy Hay	Tons	3.8	$245	$386	$545
Wheat	Bushels	103.4	$5	$474	$20
Wine Grapes	Tons	4.0	$1,008	$1,319	$2,713

Source: Adapted from Scott, 2012

Table 12. Net Farm Earnings per Acre Foot of Water by Crop and Irrigation District

Crop	Kittitas	Roza	Sunnyside	Tieton	Wapato
Alfalfa Hay	$142	$146	$143	$221	$122
Apples	$334	$333	$323	$500	$268
Asparagus	-	$187	$175	-	$150
Concord Grapes	-	$535	$469	-	$376
Hops	-	$811	$731	-	$638
Mint	-	$127	$120	-	$100
Miscellaneous	$114	$137	$132	$160	$107
Other Grain	$32	$49	$46	$69	$37
Other Hay	$33	$37	$36	$56	$29
Other Tree Crops	$1,826	$1,756	$1,680	$2,706	$1,453
Other Vegetables	$1,934	$3,242	$2,669	-	$1,953
Pasture	$109	$130	$131	-	$101
Potatoes	$452	$461	-	-	$385
Sweet Corn	$193	$196	$213	-	$182
Timothy Hay	$98	-	-	-	$85
Wheat	$4	$7	$6	-	$5
Wine Grapes	$889	$822	$720	$1,311	$577

Source: Adapted from previous tables.

Model Limitations. This model does not account for several market and behavioral factors likely to occur for agriculture under actual long-term drought conditions in the Yakima River basin. The model does not account for adaptation to drought through shifting to more drought-tolerant crops, which would likely reduce the marginal benefit of increased water supply reliability. Conversely, the model does not capture the importance of maintaining irrigation for vegetation that must survive for multiple years, such as tree crops and perennial grasses. In this way, avoiding loss of capacity to irrigate these crops would increase the value of increased water supply reliability.

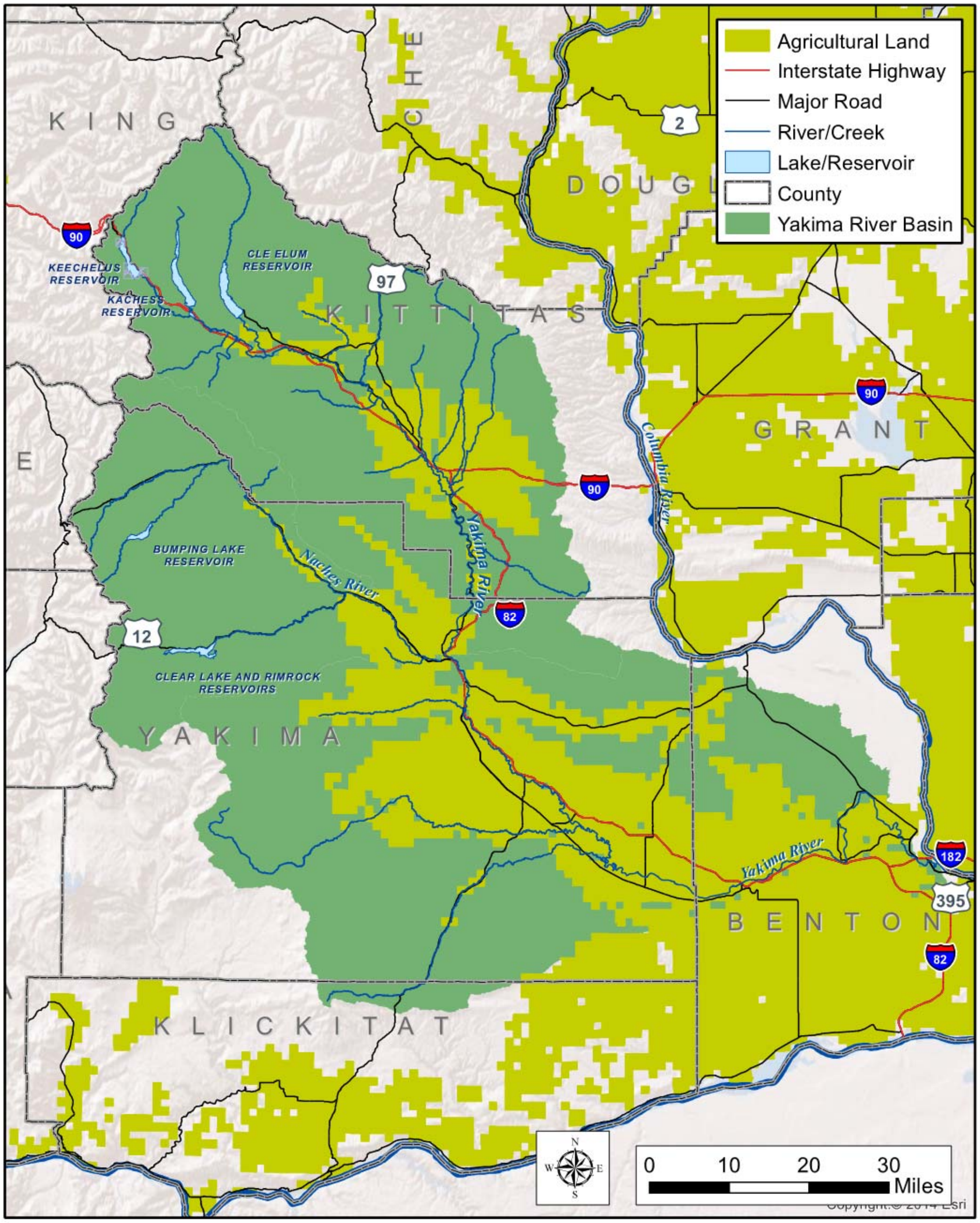
Input costs and market prices for output could respond to changes in production, and the model does not estimate these dynamics either. Reduced production under drought conditions would increase prices if there were any price response, due to increased scarcity, at least locally. Reduced production would locally reduce demand for inputs, which would lower production costs if there were any input price response. Both of these forces would reduce the magnitude of the effect of increased water supply reliability on net farm earnings. Investigations into correlations between crop prices and water availability showed little relationship locally, suggesting dominant market forces are either nonlocal or not water related (Reclamation and Ecology, 2012b).

While these exclusions from the model work in opposing directions, it is unclear which forces would be more important, and how actual effects on agriculture would occur. In general, the model does capture the primary forces driving net farm earnings, namely overall levels of production, particularly for high value crops.

One adaptation strategy would be reduced application of water on crops, thereby reducing production but not fallowing. Current technology in the Yakima River basin involves monitoring of whether or not an acre is irrigated. It does not include metering that would allow an irrigator to reduce water use on multiple acres rather than fallowing a subset. For example, a farmer cannot spread an acre's allocation across two acres and use 50 percent on each. Therefore, the model does not capture the effects on production of reduced watering for a given acre, as there currently is no incentive for such water use conservation efforts.

The model does not account for potential crop switching to adapt to drought conditions. It is unlikely, given contracts and preparation requirements, that farmers can change growing plans in response to an individual season's drought. However, in the long-term, if drought conditions become more frequent and severe, and water scarcity increases, it is likely that some crop choice decisions might lead to choice of crops that require less water or generate greater returns per acre-foot of water. This adaptation over the long-term would lessen the severity of adverse effects imposed by drought conditions.

The model does not account for potential variation in variable cost across irrigation districts other than water requirements. The water requirements vary by district in some cases because of different function and design of conveyance and irrigation. For example, proportions of diversion vs. consumption vary in some cases by district. There is no evidence that other variable costs vary systematically by district, and would vary in correlation to water availability differences across alternatives. If marginal returns to irrigation water vary more greatly in reality than specified in the model, gains from trading might be greater than represented. This would depend on how that variation aligns with proratable vs. non-proratable rights, and in which districts. If the lack of this information were to dictate that the model show no variation in crop-specific water demand by district, there would be substantially less variation across crop-acre units in the model, and consequently less opportunity to calculate likely benefits of water trading.



Source: ECONorthwest with data from Washington State Department of Agriculture - Natural Resources Assessment Section. 2013. 2013 Crop Distribution Data. Available online at http://agr.wa.gov/pestfert/natresources/aglanduse.aspx. Accessed 10/06/14. Note pixel size of 1 square mile is triggered with any agriculture identified within the pixel.

Figure 3. Agricultural Land in the Yakima River Basin

Modeling the KKC Water Supply Effects. HDR utilized historical water availability data from 1926 to 2009 to model the amount of water that would have been available to proratable users over that period under different scenarios, including had the KKC been available to water managers (Reclamation and Ecology, 2015a). Drought conditions occur throughout the timeframe, and lower prorationing levels correspond to more severe droughts. The KKC alone generates little difference from baseline conditions (Figure 4), but the KKC in combination with the KDRPP shows substantially less severe water restrictions than the baseline in the chart of actual and simulated historical conditions (Figure 5.). Under adverse climate change assumptions regarding drought severity and frequency, the pattern remains (Figure 6 and Figure 7).

The hydrologic modeling work used as the basis for the NED and RED evaluations focused on effects in years when prorationing would fall below 70% without the Integrated Plan. For this reason, results years above 70% are not included in the NED and RED analyses, and rather assumed to supply sufficient water under all alternatives. Therefore, the economic analysis team did not estimate marginal benefits of the KKC or KDRPP, or both, for years when the baseline conditions involve prorationing of 70 percent or greater.

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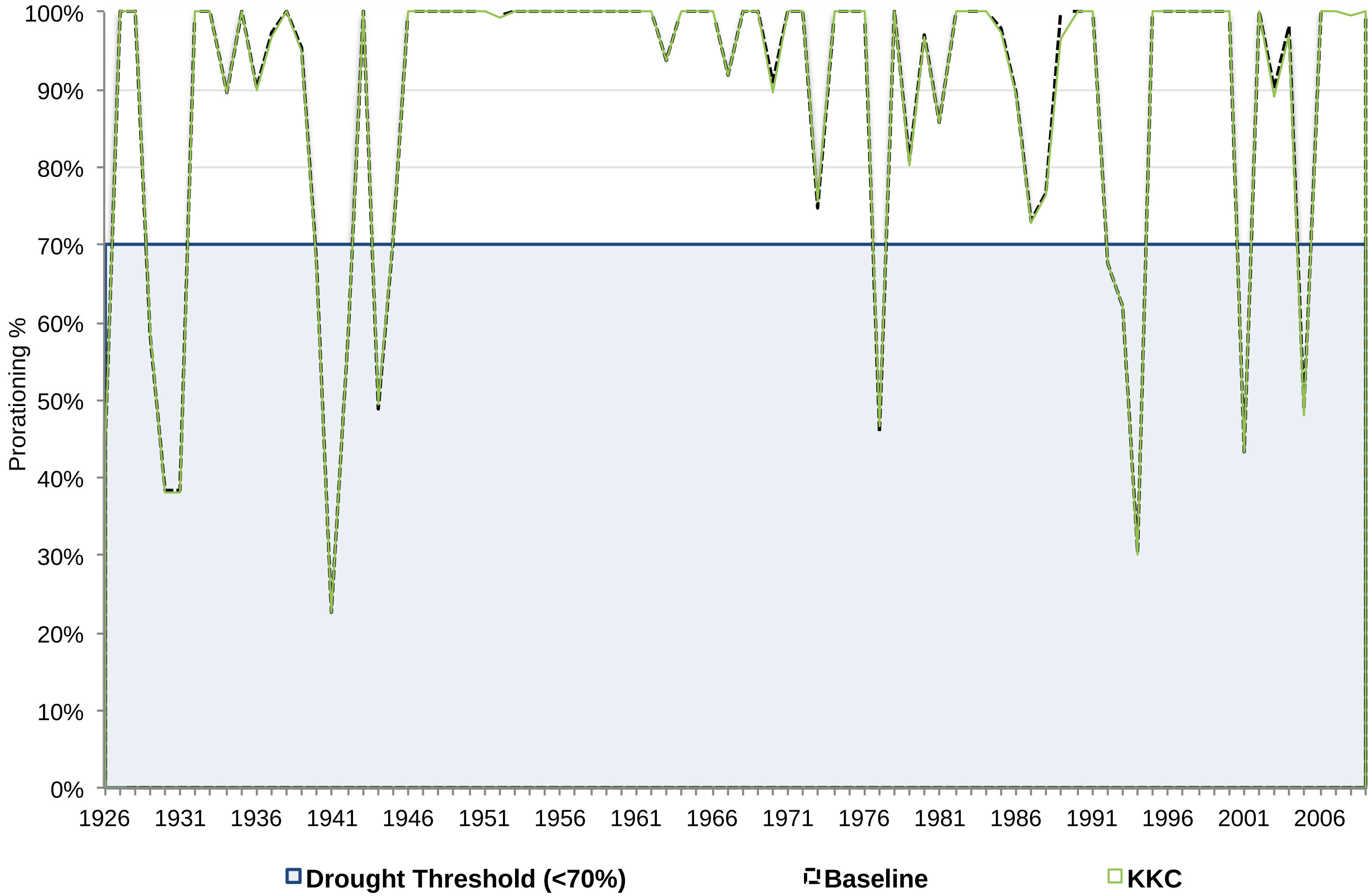
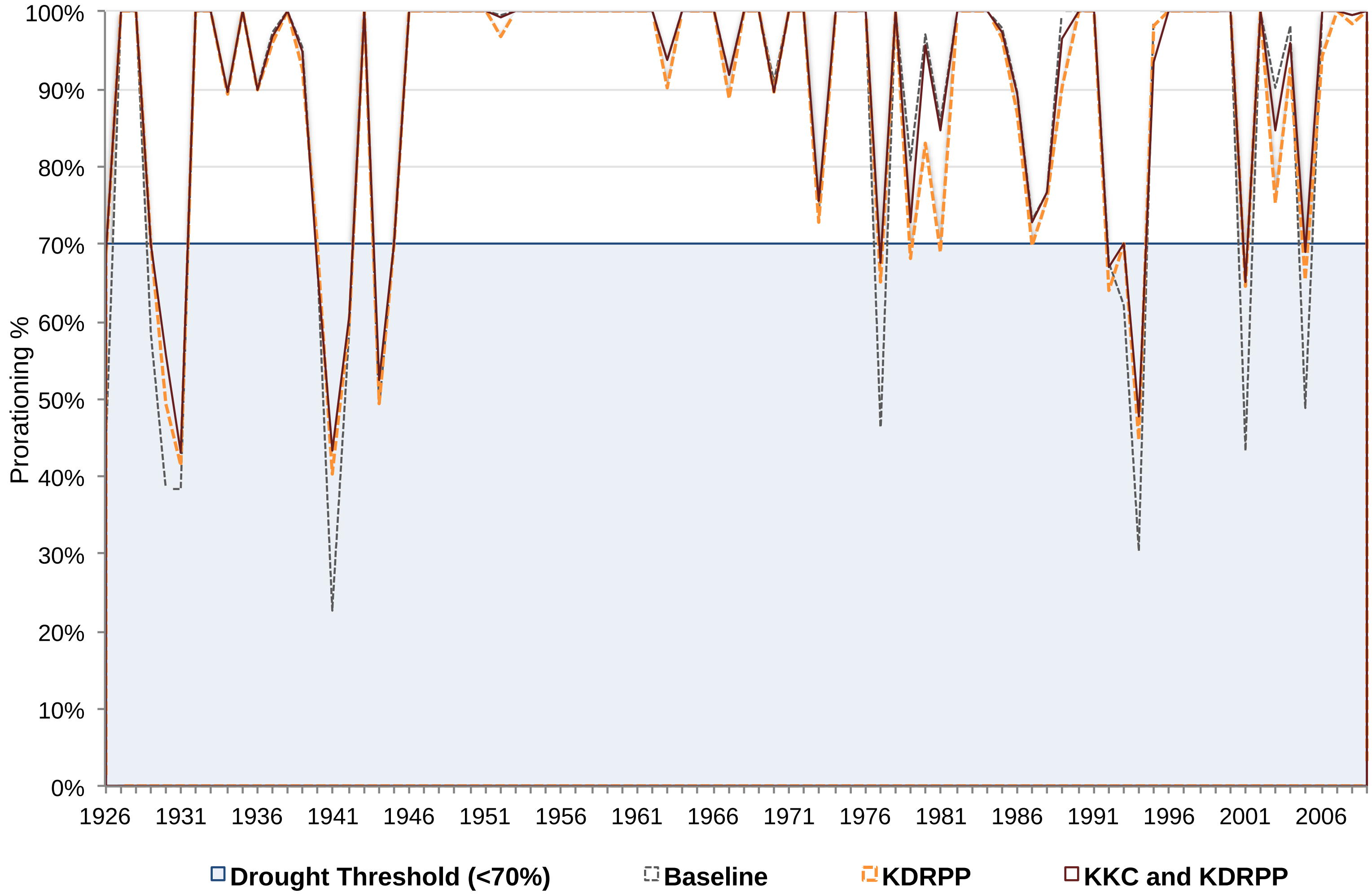


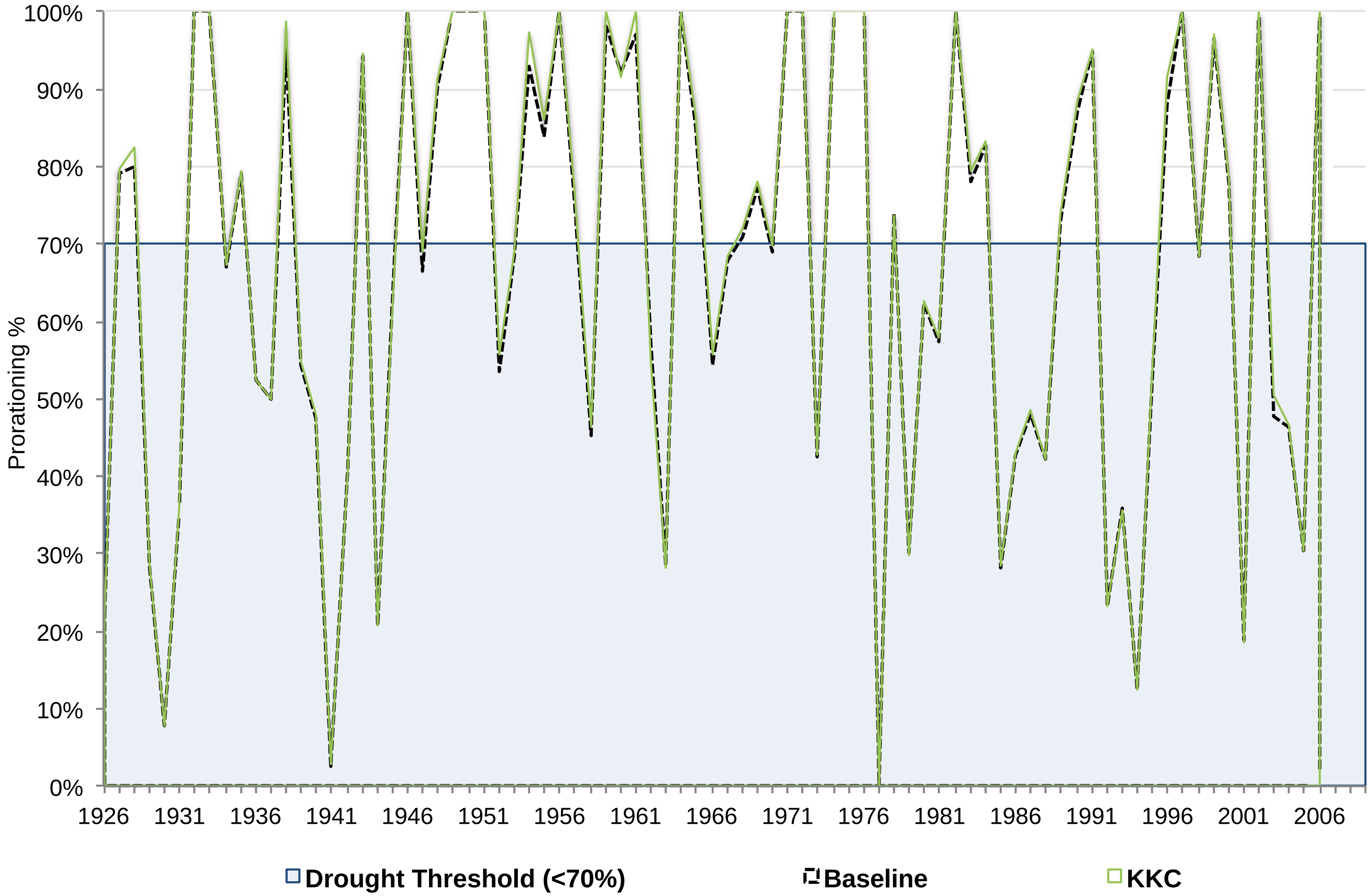
Source: ECONorthwest with data from HDR, 2014a. Note that "prorationing" refers to the share of non-drought allocation available to proratable users. For example, at 50 percent prorationing, all proratable users receive 50 percent of their non-drought allocation.

Figure 4. Predicted Water Availability Associated with the KKC, Historical Conditions, 1926 - 2009



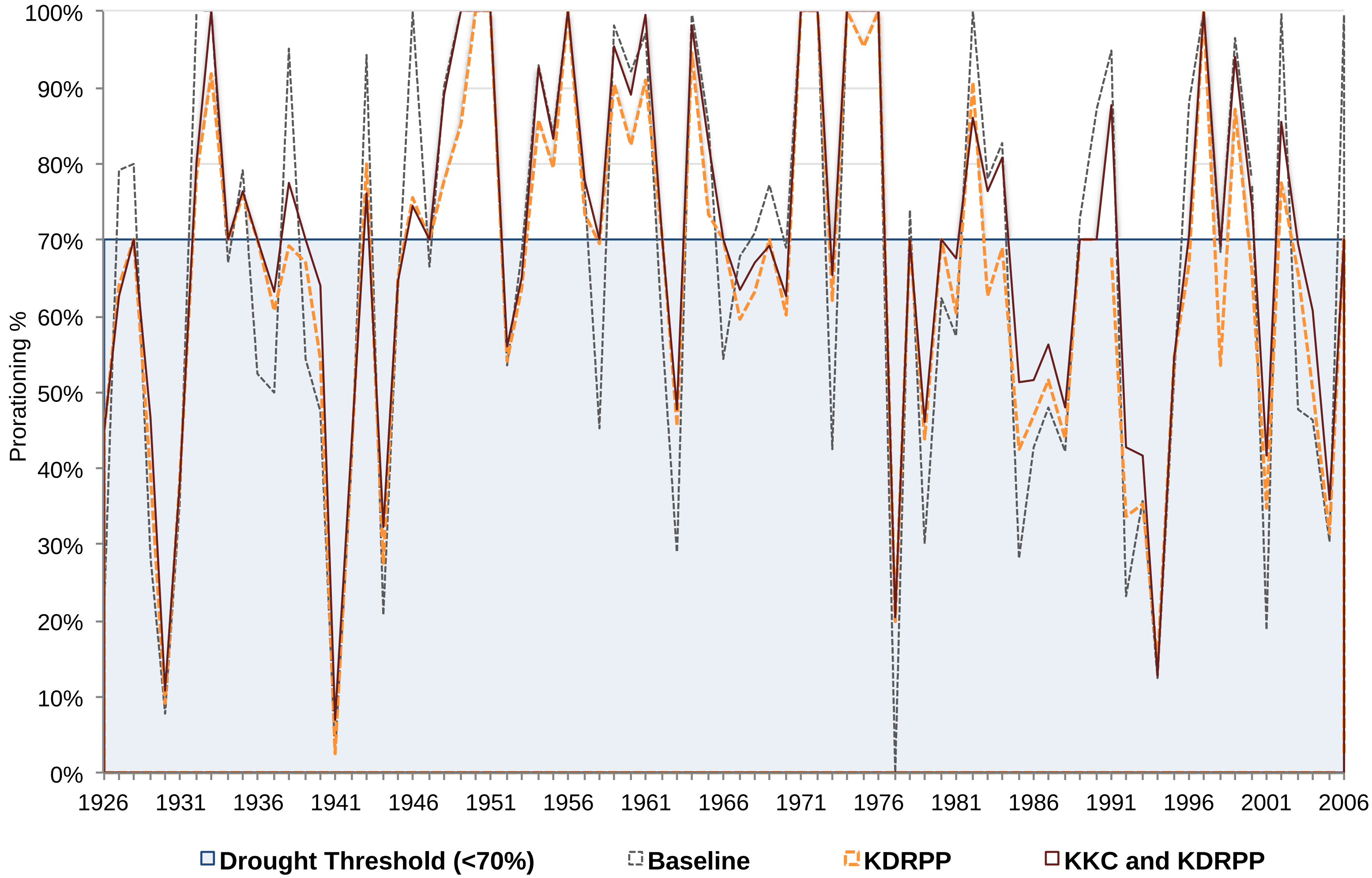
Source: ECONorthwest with data from HDR, 2014a. Note that "prorationing" refers to the share of non-drought allocation available to proratable users. For example, at 50 percent prorationing, all proratable users receive 50 percent of their non-drought allocation.

Figure 5. Predicted Water Availability Associated with the KKC and KDRPP, Historical Conditions, 1926 - 2009



Source: ECONorthwest with data from HDR, 2014a. Note that "prorationing" refers to the share of non-drought allocation available to proratable users. For example, at 50 percent prorationing, all proratable users receive 50 percent of their non-drought allocation.

Figure 6. Predicted Water Availability Associated with the KKC, and Adverse Climate Change Conditions, 1926 - 2006



Source: ECONorthwest with data from HDR, 2014a. Note that "prorationing" refers to the share of non-drought allocation available to proratable users. For example, at 50 percent prorationing, all proratable users receive 50 percent of their non-drought allocation.

Figure 7. Predicted Water Availability Associated with the KKC and KDRPP, and Adverse Climate Change Conditions, 1926 - 2006

Because of the considerable variation in net farm earnings by crop (Table 12), combined with the baseline level of market reallocation from lower-value crops to higher-value crops under drought conditions, additional water is more valuable during more severe droughts than during less severe droughts. The improvement in net farm earnings from increased water availability (reduced prorationing) grows with more high value crop acreage available to use the water that would not have been used in production but for the increased water availability. Therefore, it is important to capture the range of drought conditions and their frequencies to understand the value of increased water availability over time.

By sorting the drought years from most severe to least severe, ECONorthwest developed groups of the drought years, and used the average value for each group to represent those years. Sorting the years by most severe to the least severe drought conditions shows the differences among alternatives more clearly (Figure 8 and Figure 9). In addition, droughts of differing severity have very different economic effects, and grouping them in this way helps to illuminate those effects. Given the number of drought years, ECONorthwest defined the equally sized intervals to capture representative sets of years and manageable numbers of groups per alternative. This resulted in groups of three years under historical conditions, and groups of seven years under adverse climate change conditions. Timeframes of historical data vary because 84 years of historical drought data exist, but adverse climate change drought estimates are only available for 81 years.

The objective of this analysis is to develop an annual, probability-weighted expected value of each alternative with respect to the baseline. While historical data demonstrate that droughts occur roughly once every five years, their actual occurrence is random and unpredictable. It is, therefore, appropriate to estimate the annual probability of drought. For historical drought conditions, ECONorthwest identified five groups of three years each (Table 13). For adverse climate change conditions and the greater number of drought years, ECONorthwest identified six groups of seven years each (Table 14).

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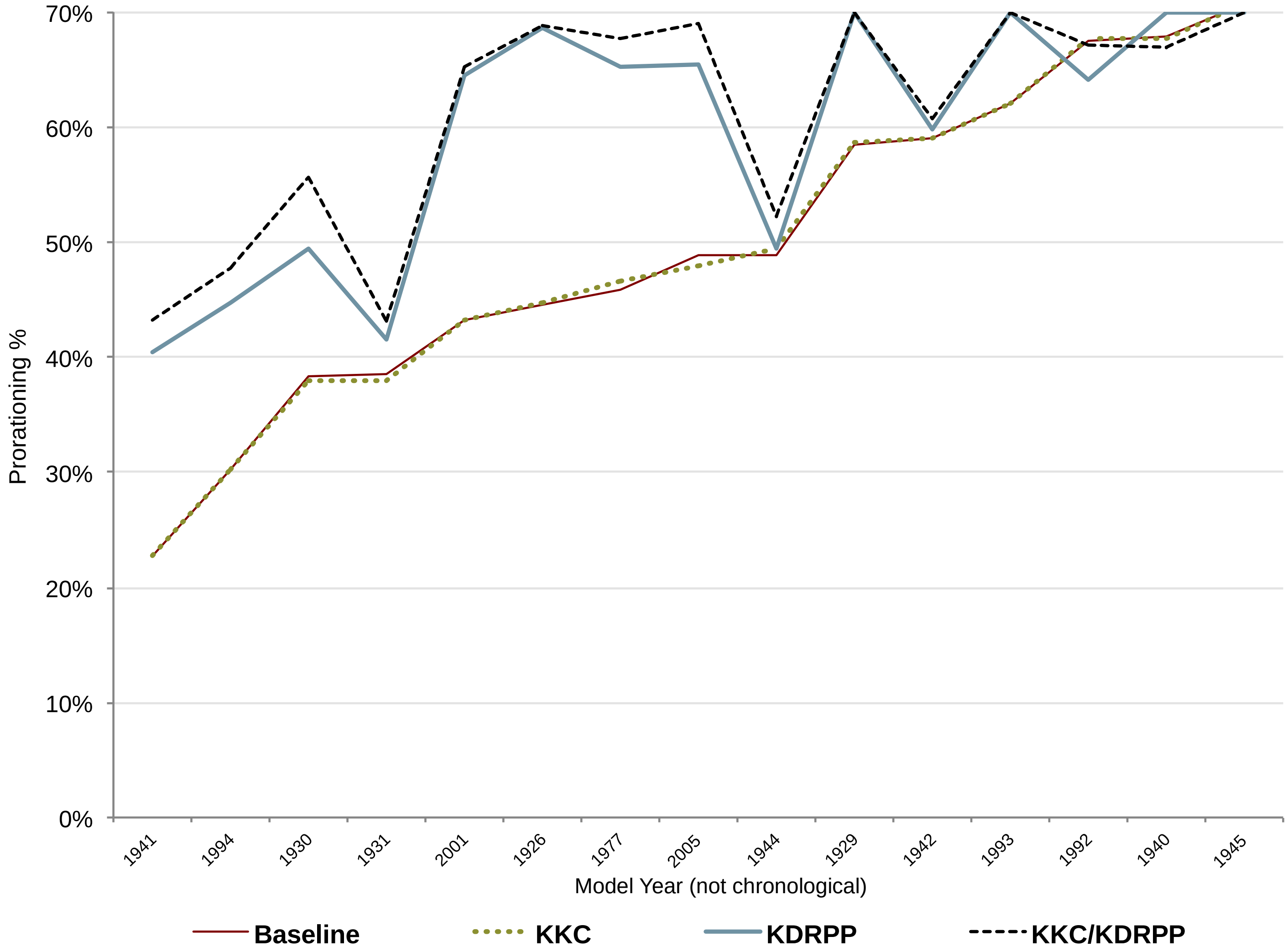
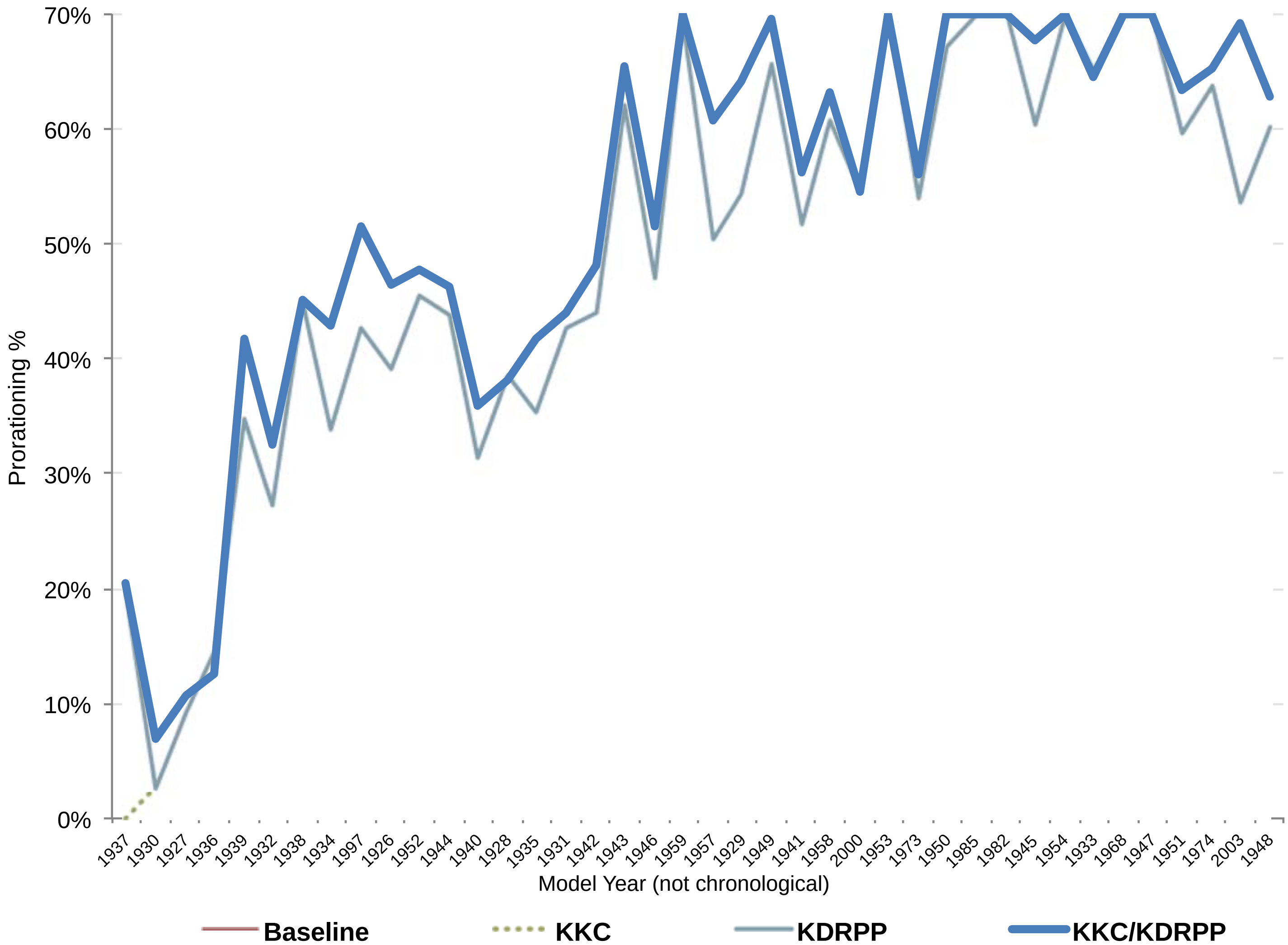


Note: Shows only years with 70 percent or less water availability. Years sorted by baseline drought conditions. Source: ECO Northwest with data from Reclamation and Ecology, 2015a.

Figure 8. Annual Prorationing Sorted by Drought Intensity, by Alternative, Historical Conditions



Note: Group shows average midpoint for baseline conditions. Years sorted by baseline drought conditions. Source: ECONorthwest with data from Reclamation and Ecology, 2015a.

Figure 9. Annual Prorationing Sorted by Drought Intensity, by Alternative, Adverse Climate Change

Table 13. Sorted Groups of Water Availability by Scenario, Historical Conditions

Group Range - 3 Years	Baseline	KKC	KDRPP	KKC and KDRPP
Group 1 – 1941, 1994, 1930	30%	30%	42%	45%
Group 2 – 1931, 2001, 1926	42%	42%	61%	63%
Group 3 – 1977, 2005, 1944	48%	48%	60%	63%
Group 4 – 1929, 1942, 1993	60%	60%	67%	67%
Group 5 – 1992, 1940, 1945	69%	69%	68%	68%

Note: Table values represent the average prorationing level for each group. Years for groups defined by ordering of baseline years from most to least severe droughts in historical record from 1926-2009, and using fixed interval lengths of 3 years. See Reclamation and Ecology, 2015a for drought simulation data and methodology.

Table 14. Sorted Groups of Water Availability by Scenario, Adverse Climate Change

Group Range - 7 Years	Baseline	KKC	KDRPP	KKC and KDRPP
Group 1	12%	12%	22%	24%
Group 2	29%	29%	39%	44%
Group 3	42%	43%	50%	55%
Group 4	50%	51%	59%	62%
Group 5	59%	60%	67%	69%
Group 6	69%	70%	63%	67%

Note: Years not shown for each group due to space constraints, but listed on figure axis. Table values represent the average prorationing level for each group. Years for groups defined by ordering of baseline years from most to least severe droughts as simulated extrapolating from 1926-2006 record, and using fixed interval lengths of 7 years. See Reclamation and Ecology, 2015a for drought simulation data and methodology.

These groups demonstrate the relative water availability with and without the KKC. The KKC provides little improvement compared with baseline conditions. However, the KKC adds a distinct increment of water availability when installed together with the KDRPP (see Groups 1, 2, and 3 in Figure 10 and Figure 11). This effect is stronger under adverse climate change conditions (Figure 12 and Figure 13).

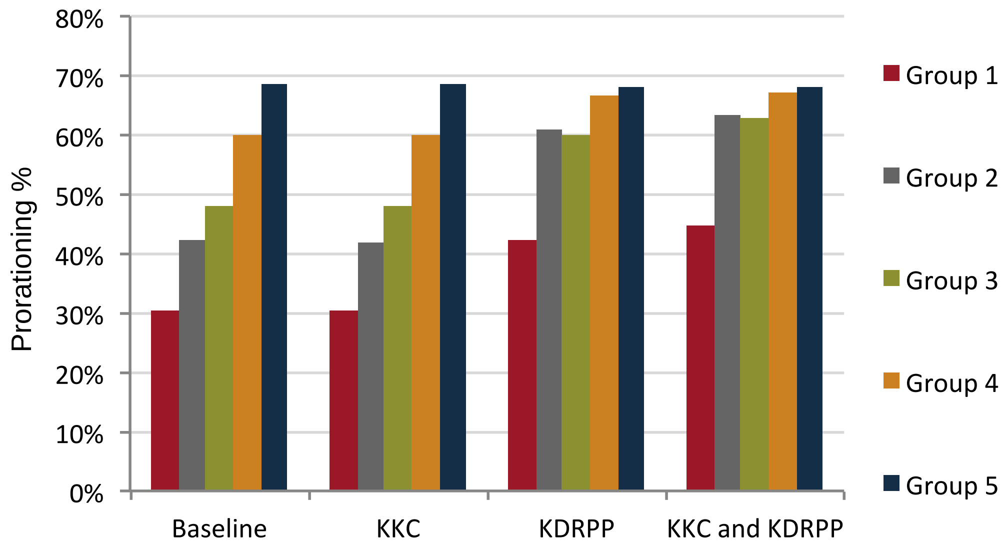


Figure 10. Sorted Groups of Water Availability by Scenario, Historical Conditions

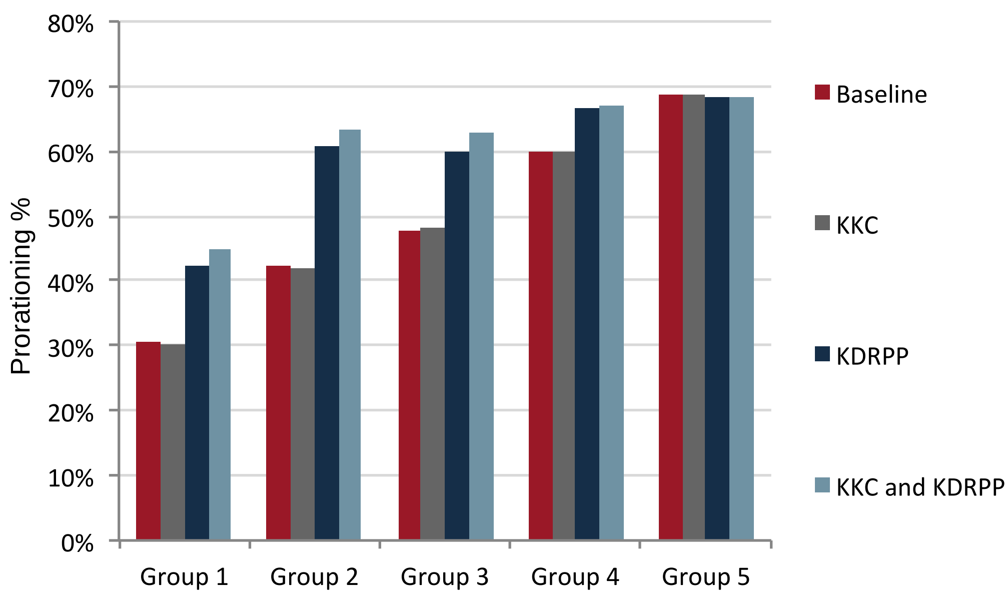


Figure 11. Drought Year Groups by Alternative, Historical Conditions

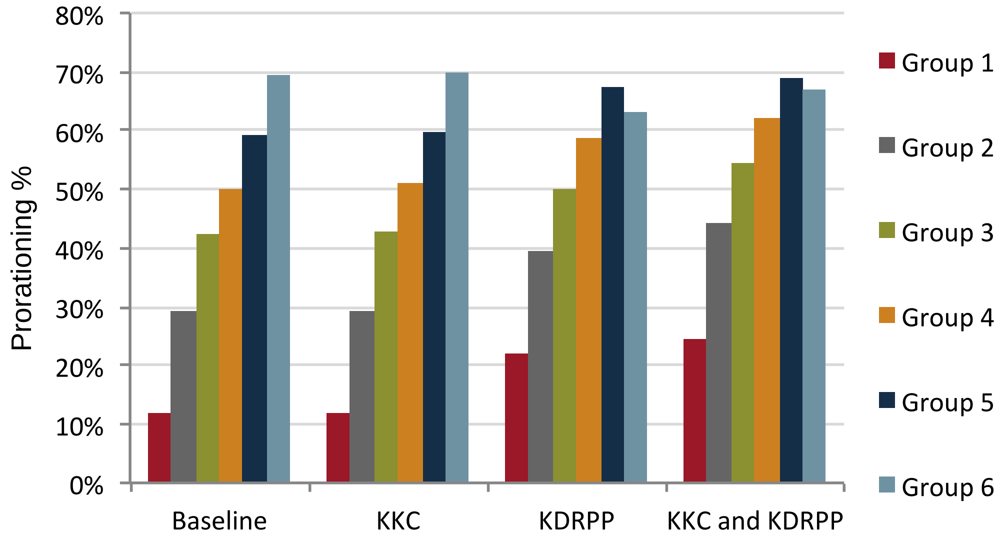


Figure 12. Sorted Groups of Water Availability by Scenario, Adverse Climate Change

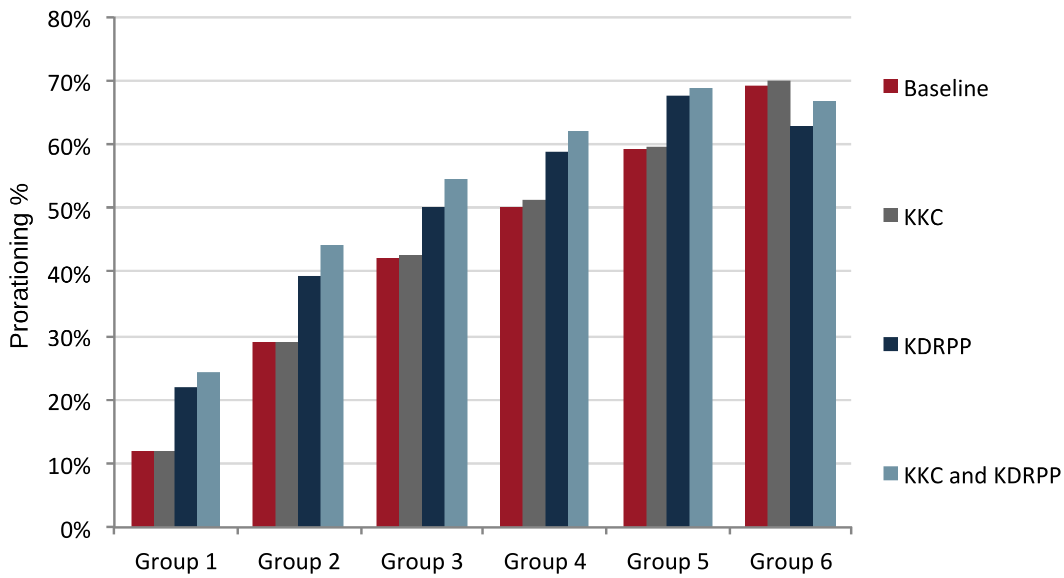


Figure 13. Drought Year Groups by Alternative, Adverse Climate Change

ECONorthwest calculated the net farm earnings for the average prorationing level of each group (Table 15 and Table 18). Net farm earnings in this context refer to gross earnings minus costs. Under historical conditions, the alternative of the KKC alone provided little improvement in earnings. When combined with the KDRPP, the KKC does provide additional earnings (Table 15 and Table 16). When probabilistically weighing groups across all years, the KKC provides no benefit beyond the baseline, while it provides over $1 million annually when combined with the KDRPP relative to the KDRPP alone (Table 17). Over 100 years discounted at 3.375 percent, this equates to a NPV of $34 million that the KKC contributes when added to the KDRPP.

Table 15. Annual Net Farm Earnings by Water Availability Group, Historical Conditions

Group Range - 3 Years	Baseline	KKC	KDRPP	KKC and KDRPP
Group 1	$451,704,774	$450,997,233	$508,417,302	$520,225,929
Group 2	$507,693,204	$507,290,657	$588,435,675	$597,471,905
Group 3	$535,458,100	$535,896,403	$585,350,084	$596,516,182
Group 4	$584,832,116	$585,186,394	$609,863,778	$610,877,794
Group 5	$616,833,454	$616,850,350	$614,527,351	$614,548,186

Note: Values represent model estimates for net farm earnings based on average prorationing level for each group.

Table 16. Annual Net Farm Earnings by Water Availability Group Net of Baseline, Historical Conditions

Group Range - 3 Years	Baseline	KKC	KDRPP	KKC and KDRPP
Group 1	-	-$707,540	$56,712,529	$68,521,156
Group 2	-	-$402,547	$80,742,471	$89,778,701
Group 3	-	$438,303	$49,891,985	$61,058,082
Group 4	-	$354,278	$25,031,662	$26,045,678
Group 5	-	$16,896	-$2,306,103	-$2,285,268

Note: Values represents differences between baseline and each alternative model estimates for net farm earnings based on average prorationing level for each group.

Table 17. Composite Net Farm Earnings and Net of Baseline, Annually and 100-Year Net Present Value, Historical Conditions

	Baseline	KKC	KDRPP	KKC and KDRPP
Group Composite	$96,304,345	$96,293,608	$103,806,935	$104,987,143
versus Baseline	-	-$10,736	$7,502,591	$8,682,798
NPV (Total Earnings)	$2,750,228,752	$2,749,922,155	$2,964,485,347	$2,998,189,333
NPV (Marginal Earnings)	-	-$306,598	$214,256,595	$247,960,580

Note: Values based on weighting by overall sample size of all years (drought and non-drought) from results of preceding tables.

Similar patterns and results exist under adverse climate change conditions, although the KKC alone does provide benefits beyond the baseline. The benefits of the addition of the KKC to the KDRPP Alternative are significantly greater with climate change than under historical conditions (Table 18 and Table 19). The annual benefit for the KKC alone in the composite (weighted) alternative is $730,000, and is $7 million when combined with the KDRPP (Table 20). For calculation of NPV under adverse climate change conditions, the analysis assumes that the adverse conditions begin 20 years into operation, so the values under historical conditions described above apply for the first 20 years, and the adverse climate change conditions apply for the remaining 80 years. These assumptions equate to a NPV of $10 million for the KKC alone, and $117 million when combined with the KDRPP beyond the benefits of the KDRPP alone.

Table 18. Annual Net Farm Earnings by Group Water Availability, Adverse Climate Change

Group Range - 7 Years	Baseline	KKC	KDRPP	KKC and KDRPP
Group 1	$362,193,300	$362,221,510	$409,821,367	$421,542,299
Group 2	$445,426,731	$445,780,660	$494,074,387	$517,437,918
Group 3	$508,637,146	$510,008,828	$545,160,207	$563,098,334
Group 4	$545,293,503	$549,271,338	$580,270,726	$592,774,043
Group 5	$582,921,795	$583,939,729	$612,770,045	$617,364,813
Group 6	$618,469,981	$620,475,392	$596,298,033	$610,412,800

Note: Values represent model estimates for net farm earnings based on average prorationing level for each group.

Table 19. Annual Net Farm Earnings by Group Water Availability Net of Baseline, Adverse Climate Change

Group Range - 7 Years	BASELINE	KKC	KDRPP	KKC and KDRPP
Group 1	-	$28,210	$47,628,067	$59,348,998
Group 2	-	$353,928	$48,647,656	$72,011,186
Group 3	-	$1,371,682	$36,523,061	$54,461,188
Group 4	-	$3,977,835	$34,977,224	$47,480,540
Group 5	-	$1,017,934	$29,848,250	$34,443,018
Group 6	-	$2,005,410	-$22,171,948	-$8,057,182

Note: Values represents differences between baseline and each alternative model estimates for net farm earnings based on average prorationing level for each group.

Table 20. Composite Net Farming Earnings and Net of Baseline, Annually and 100-Year Net Present Value, Adverse Climate Change

	Baseline	KKC	KDRPP	KKC and KDRPP
Group Composite	$255,245,205	$255,974,788	$269,866,231	$276,885,850
versus Baseline	-	$729,583	$14,621,026	$21,640,646
NPV (Total Earnings)	$5,004,515,013	$5,014,708,496	$5,319,733,627	$5,436,259,031
NPV (Marginal Earnings)		$10,193,482	$315,218,614	$431,744,018

Note: Values based on weighting by overall sample size of all years (drought and non-drought) from results of preceding tables.

Overall, the benefits of the KKC for agriculture through reduced prorationing during droughts can reach into the millions of dollars annually when viewed as a complementary addition to the KDRPP. Benefits of the KKC to agricultural earnings without the KDRPP are low to nonexistent. (Negative values shown in model results are due to model limitations related to using the same operational rules in all years. In actual practice, Reclamation would operate the KKC in a way that would avoid negative effects on prorationing.) If the KDRPP were implemented, the complementary addition of the KKC could be worth over $100 million over 100 years (Table 21).

There is considerable uncertainty regarding likely future drought severity and frequency patterns for the Yakima River basin. Choosing varying lengths of historical data generate quite varied average annual estimates. When combined with adverse climate conditions, these estimates can vary even more widely. Without assuming historical conditions for the first 20 years of the timeframe, and rather assuming adverse climate change conditions for the entire 100-year timeframe, the incremental benefit of the KKC combined with the KDRPP would climb from $117 million to $200 million. This may be relevant because Reclamation and Ecology cannot know for certain whether climate change conditions are, or are not, already affecting the frequency and severity of droughts in the Yakima River basin.

Table 21. Net Farm Earnings Benefits of the KKC

	KKC Alone	KKC when Added to KDRPP
Annual, with Historical Conditions	-	$1.1 million
100-Year NPV, with Historical Conditions	-	$34 million
Annual, with Climate Change	$730,000	$7 million
100-Year NPV, with Climate Change	$10.2 million	$117 million

Water Supply for Municipal Use

The City of Yakima has 5,083 acre-feet of proratable entitlements, as well as other water rights (Reclamation and Ecology, 2011). The city is moving forward with plans for aquifer storage and recovery (ASR) by injecting water through its wells into the aquifer during non-drought years, and anticipates meeting all drought needs via this strategy. Currently, the city has two wells capable of ASR, and two additional wells would provide sufficient capacity. It is still in the process of obtaining permits to conduct ASR from the State, but in 2014 demonstrated its technical feasibility.

Yakima's water manager reported that the appropriate tradeoff for valuation of water supply is avoided groundwater pumping during droughts. The city reports that the operation of one of its groundwater well pumps with a capacity of 3,000 gallons per minute costs $20,000 a month. This equates to $50 per acre-foot of water. This cost per acre-foot of water is within the ranges discussed in the technical report describing the ASR program (Golder, 2014).

Examining years experiencing droughts during baseline conditions (historical and adverse climate change), the KKC provides no benefit for the average drought over the baseline under historical conditions, and 0.3 percent improvement under adverse climate change conditions (Table 22). Pumping costs do not vary with drought severity, so it is not necessary to account for different drought severities as with agriculture. During the average drought year, the KKC provides benefits under adverse climate change that equate to approximately 17 acre-feet and $842 in avoided pumping costs. Accounting for the frequency of droughts, this is an expected average annual value of $416, which discounted over 100 years equates to $11,872. The gains for the KKC over KDRPP alone though are $20,879 over 100 years under historical conditions, and $71,165 under adverse climate change. As with irrigation benefits, the net present value for municipal benefits in this section under adverse climate change assume historical conditions for the first 20 years, followed by adverse climate change conditions for the following 80 years.

Table 22. Avoided City of Yakima Municipal Groundwater Pumping Costs, Historical and Adverse Climate Change Conditions

Scenario	Prorationing	Acre-Feet Available	Drought Year Avoided Cost	Average Annual	NPV
Baseline	48.3%	2,456	-	-	-
KKC only	48.3%	2,455	$0	$0	$0
KDRPP only	58.8%	2,989	$26,416	$4,403	$125,734
KKC and KDRPP	60.5%	3,077	$30,803	$5,133	$146,612
Baseline CC	42.3%	2,150	-	-	-
KKC only, CC	42.6%	2,167	$842	$416	$5,896
KDRPP only, CC	49.2%	2,503	$17,461	$8,623	$185,584
KKC and KDRPP, CC	52.7%	2,677	$26,120	$12,899	$256,748

Source: Avoided costs based on Brown, 2014. City of Yakima water rights based upon Reclamation and Ecology, 2011.
CC = climate change

The City of Ellensburg also has proratable water rights of 6,000 acre-feet (Reclamation and Ecology, 2011). Ellensburg does not yet have an ASR program. Assuming drought could force Ellensburg to purchase water as described and analyzed in Reclamation and Ecology 2012b, the acquisition costs would be $267 per acre-foot in 2014 dollars. Under these assumptions, the KKC as an addition to the KDRPP, in terms of the value of increased water reliability and reduced water purchase costs, would provide a benefit worth $27,994 during the average drought year under historical conditions and $55,167 during the average drought year under adverse climate change conditions (Table 23). The greater frequency of drought years under adverse climate change equates to $453,000 in net present value over 100 years for adverse climate change, while historical conditions would experience $133,000 in net present value over 100 years.

Table 23. Avoided City of Ellensburg Municipal Water Purchase Costs

Scenario	Prorationing	Acre-Feet Available	Drought Year Avoided Cost	Average Annual	NPV
Baseline	48.3%	2,899	-	-	-
KKC only	48.3%	2,898	$0	$0	$0
KDRPP only	58.8%	3,528	$168,282	$28,047	$800,958
KKC and KDRPP	60.5%	3,633	$196,226	$32,704	$933,961
Baseline CC	42.3%	2,538	-	-	-
KKC only, CC	42.6%	2,558	$5,363	$2,648	$37,562
KDRPP only, CC	49.2%	2,954	$111,230	$54,928	$1,182,219
KKC and KDRPP, CC	52.7%	3,160	$166,397	$82,171	$1,635,558

Source: Avoided costs based on Brown, 2014. City of Yakima water rights based upon Reclamation and Ecology, 2011.

Table 24. Avoided Municipal Water Costs, Cities of Yakima and Ellensburg Combined

Scenario	Prorationing	Acre-Feet Available	Drought Year Avoided Cost	Average Annual	NPV
Baseline	48.3%	5,355	-	-	-
KKC only	48.3%	5,353	$0	$0	$926,691
KDRPP only	58.8%	6,517	$194,698	$32,449	$1,080,573
KKC and KDRPP	60.5%	6,710	$227,029	$37,837	
Baseline CC	42.3%	4,688	-	-	$43,458
KKC only, CC	42.6%	4,725	$6,205	$3,064	$1,367,802
KDRPP only, CC	49.2%	5,457	$128,691	$63,551	$1,892,306
KKC and KDRPP, CC	52.7%	5,837	$192,517	$95,070	$926,691

Source: Avoided costs based on Brown, 2014. City of Yakima water rights based upon Reclamation and Ecology, 2011.

The sum of these benefits for the two communities, if measuring the KKC's contribution as the difference between benefits of the KDRPP alone and the KDRPP with the KKC, would be $154,000 to $524,500 over the 100-year timeframe (Table 24) in terms of avoided costs associated with water pumping and water purchase. If an ASR program were developed for Ellensburg, these avoided costs would be less in total for the two cities, while if ASR is unsuccessful and Yakima would also be required to purchase water, the avoided costs could climb in value. If only considering the KKC benefits in terms of the contribution of the KKC alone, the net present value under adverse climate change would be $43,000.

Fish Production from the Keechelus Reach of the Yakima River

By enabling the transfer of water from Keechelus Reservoir to Kachess Reservoir, the KKC would enable Reclamation to reduce high flows that occur in the Keechelus Reach of the Yakima River because of releases from Keechelus Reservoir for water supply. Reclamation and other agencies' (including NMFS, WDFW, Yakama Nation, and USFWS) fishery biologists recognize that this improvement in flow conditions during the late summer would improve rearing conditions for spring Chinook salmon, thereby increasing fisheries productivity in this reach.[1] Reclamation fishery biologists estimate an annual increase by roughly a factor of 10 because of this effect. These benefits would begin to accrue in the first year of the 100-year period of analysis (after construction is complete) and annually thereafter. As described below, Reclamation assumes that these benefits will increase linearly over 20 years, from the baseline conditions to the full potential benefit and will remain constant after the first 20 years. The KDRPP does not contribute to this effect.

Table 25. Annual Change in Adult Spring Chinook in the Keechelus Reach of the Yakima River

	Baseline	KKC	Change
Minimum	48	463	416
Average	169	1,646	1,477
Maximum	479	4,660	4,181

Source: Bureau of Reclamation, Joel Hubble. 2014. Expected Improvement in Fish Productivity in the Keechelus Reach with Implementation of the Proposed Keechelus-to-Kachess Conveyance. October 28.

Similar to Chinook, biologists expect steelhead to benefit from streamflow modifications on the Keechelus Reach. Currently, steelhead do not populate the Keechelus Reach. There is a trend of steelhead expansion into the upper Yakima River basin, but the same high flow conditions described above would limit this trend in the Keechelus Reach. Federal biologists estimate production of 550 to 910 (rounded) adult steelhead would occur annually in the Keechelus Reach with the KKC. They estimate 10 percent of this number could be achieved due to natural expansion of steelhead range, without the KKC.

Table 26. Annual Change in Adult Steelhead in the Keechelus Reach of the Yakima River

	Baseline	KKC	Change
Minimum	60	610	550
Average	80	810	730
Maximum	100	1,010	910

Source: Bureau of Reclamation, Joel Hubble. 2014. Expected Improvement in Fish Productivity in the Keechelus Reach with Implementation of the Proposed Keechelus-to-Kachess Conveyance. October 28.

[1] Meetings and discussions for fish population estimates included National Marine Fisheries Service, Washington Department of Fish and Wildlife, the Yakama Nation, and the U.S. Fish and Wildlife Service.

Fish Value

In 1999, Ecology commissioned the development and application of a model (LBP Study*)* for estimating the total economic value of benefits derived from potential future programs to increase fish populations in waterways across the State (Layton et al., 1999). Though never published in an academic journal, the model has received considerable peer review through other channels. One review recommends the assignment of values based upon the methodology developed in the model for any reliable estimates of impacts on salmon and steelhead in the Columbia River Basin (Huppert et al., 2004). A thorough review of the methodology and validation across other sources is available in the 2012 Four Accounts study for the overall Integrated Plan.

The LBP Study does not differentiate between use and passive use values, although given the State-wide application of the estimates, it is appropriate to interpret them as primarily passive use values. Analyses of commercial and sport use values for these fisheries as part of the 2012 Four Accounts study suggested that use values are likely 2 to 4 percent of these total economic values of the fish population benefits.

The LBP Study relies upon sophisticated interpolation from survey results in consideration of a change in overall salmonid population sizes in terms of percentages in the Columbia River Basin, over 20-year periods. It accounts for declining marginal value with improvements to the various salmonid populations. For consistency with the 2012 Four Accounts study moving forward, Reclamation interpolates a value for salmonid production attributable to the KKC as a proportion of the overall Integrated Plan estimated salmonid benefits. Similarly, in an interview in 2012 with one of the study's authors, Mark Plummer, he suggested that the results are not appropriate for applying to extremely small changes in fish populations. It is most rigorous to consider the overall Integrated Plan benefits, but then consider an appropriate share of those benefits for each project, to the extent that the team can assign a share.

In the 2012 Four Accounts study, the overall salmonid population improvement estimates evaluated were based on annual increases over 30 years, plateauing at 181,650 to 472,450 fish per year after 30 years. The improvements available under the KKC after summing Chinook and steelhead production and aligning the corresponding range maxima and minima represent 0.5 percent of the low end to 1.1 percent of the high end of the overall Integrated Plan benefit estimates. These improvements equate to value in the range of $18 to $54 million over 40 years for Washington residents, and $29 to $86 million when including Oregon residents (Table 27). The values are not applied for years more than 40 out in the timeframe, because the LBP model is not specified for such long-term interpretation of willingness-to-pay values. It is likely that benefits would continue to accrue, but are not calculated in this analysis.

As stated above, it is inappropriate to interpret the LBP Study results directly for a value of such a small change in fish population size. Rather, it is appropriate to consider the overall value of the Integrated Plan's improvements in fish population sizes, of up to 60 percent increase over baseline levels, and consider the likely share of this improvement contributed by the KKC, within the ranges provided.

Table 27. Present Value of KKC Keechelus Reach Salmon Benefits (2014$)

	Percent of Total Integrated Plan Increase	Washington	Washington and Oregon
Minimum	0.5%	$18.3 million	$29.1 million
Maximum	1.1%	$54.3 million	$86.3 million

Source: Based on calculations in Reclamation and Ecology, 2012b. Updated to 2014 dollars, with 3.375% discount rate.

3.2.2 Unquantified Benefits

The KKC has other categories of potential benefits that could arise that are unquantified at this point. The increased flexibility and option value of the KKC operations, both for consumptive uses (primarily irrigation) and instream habitat effects, would likely provide situational benefits that are difficult to predict at this time. Water transactions, for example, require adaptability so that water can be used even if the geography or timing of demand varies somewhat. This can hold for both out-of-stream and instream uses.

The option value might also allow more efficient uses of other components of water supply systems in the Yakima River basin. For example, if additional storage or diversion capacity were available, Reclamation might use other storage more freely, such as drawing down another reservoir to lower levels that might otherwise seem too risky without increased options for storage and diversion with the KKC.

The KKC would accelerate refill of the proposed the KDRPP if the KDRPP were constructed. This, in turn, would lessen potential impacts that KDRPP would have on bull trout, particularly at times when drawdown of Kachess Reservoir hampers bull trout movement from the main Kachess Reservoir into the upstream portion known as Little Kachess Lake. Accelerating refill would also reduce impacts to recreational users from drawdown of Kachess Reservoir by the KDRPP.

The KKC is linked indirectly to habitat conservation within the Teanaway Community Forest (TCF), which was established by the Washington State Legislature in 2013. State legislation empowered the State Department of Natural Resources (DNR) to manage the TCF for a range of purposes, including fish habitat conservation and restoration as a top priority. The TCF was established as an element of the Integrated Plan, and the legislation explicitly authorizes DNR to alter the TCF management objectives after 2025 if certain water supply objectives under the Integrated Plan are not met by 2025. These objectives would largely be met if the KDRPP were constructed. Since the KKC would enhance viability of the KDRPP as discussed above, there is a linkage between implementation of the KKC and the long-term management of the TCF for fish habitat conservation.

Development of the Integrated Plan involved collaboration with a wide range of stakeholders. Some of these stakeholders have been parties to litigation in the past over water resource management and fisheries management in the Yakima River basin. The Yakama Nation has been a litigant in past court proceedings; and the Federal government has trust responsibility for Native American populations comprising the Yakama Nation. Implementation of the Integrated Plan, including the KKC, is expected to reduce the likelihood of potential future litigation involving Reclamation facilities and operations, or the State of Washington's management of water resources and fisheries in the Yakima River basin. This would not only avoid direct costs of legal proceedings, but also reduce uncertainty over how agencies would manage water resources and fisheries. These effects represent benefits to a range of stakeholders including the Yakama Nation, Yakima River basin irrigators and farm operators, local city and county governments, and non-governmental organizations with an interest in natural resource management in the Yakima River basin and Pacific Northwest region.

Bull Trout Enhancement Program

The U.S. Fish and Wildlife Service listed bull trout populations in both Keechelus Reservoir and Kachess Reservoir watersheds as "threatened" under the Endangered Species Act. These two sub-populations are among the numerically lowest populations in the Yakima River basin. The BTE program would generate long-term benefits for bull trout populations in both the Keechelus and Kachess Reservoir watersheds. Reclamation and Ecology would activate the BTE in conjunction with either the KKC or KDRPP.

Reestablished year-round tributary passage between Gold Creek, Cold Creek, and potentially upper Kachess River into the reservoirs would increase the number of spawners and redds deposited that otherwise would be precluded from spawning that year. While quantitative projections are not available, Federal biologists indicate this would lead to increased population productivity and abundance. Artificial nutrient enrichment of these watersheds would most directly increase juvenile abundance with the expected improvement in the prey base for sub-adult and adult bull trout residing in the reservoirs. This would also result in expected increase in growth, condition factors, and survival rates, which over time would result in an increase in population abundance and productivity. In addition, artificial nutrient enrichment would be beneficial to the future reintroduction of sockeye into these two reservoirs. If proven feasible, there is the potential to expand the amount of spawning and juvenile rearing habitat in Box Canyon Creek above the falls by approximately 3 miles, which would lead to increased population abundance for the Box Canyon population. Reestablished passage into Cold Creek in the Keechelus Reservoir would open up approximately 2.2 miles of habitat that is currently inaccessible.

The BTE plan also has the potential to accelerate the rate of population recovery greatly in terms of abundance and increased genetic diversity for the Keechelus and Kachess populations by translocation of fish from healthier populations in the Yakima River basin.

Reclamation expects these collective actions to increase bull trout abundance, productivity, and genetic diversity for the Keechelus and Kachess populations. Because of these actions, these populations should become more resilient to the natural fluctuation in environmental factors that can negatively impact population abundance and productivity. These actions would also provide benefits for overall ecosystem health in the reservoirs and their tributaries.

Bull trout are a particularly scarce fish species, and high scarcity creates opportunities for high value improvements. Research on the value of listed threatened and endangered species consistently demonstrates the substantial importance to people of protecting and maintaining these rare species (Loomis and White, 1996). Reclamation has not quantified the value of the BTE program because the small fish populations involved are difficult to model accurately, and because means of establishing monetary equivalents are not readily available.

3.2.3 Quantified Costs

The KKC involves two alternative construction options based upon two tunnel alignments: the North Tunnel Alternative and South Tunnel Alternative. Both alternatives would take an estimated three years of construction to complete. Both alternatives involve annual operation and maintenance expenses, including energy costs (HDR, 2014b). They also involve intermittent additional costs over time, the largest of which involves some capital equipment replacement at 50 years. Together, these costs are $272 million undiscounted or $258 million present value for the North Tunnel Alternative, and $306 million undiscounted or $291 million discounted for the South Tunnel Alternative (Table 28 and Table 29). Observing the occurrence of these costs over time, the capital construction costs over the first three years dominate overall costs (Figure 14).

Table 28. Project Costs and Discounted Present Value, North Tunnel Alternative

Cost Category	Total	Present Value
Field Costs	$ 206,413,000	N/A
Noncontract Costs	$34,400,000	N/A
Interest During Construction	$12,421,285	N/A
Annual OMR&P	$13,660,000	$3,900,979
O&M	$12,760,000	$3,643,960
Power	$ 900,000	$257,019
Non-Annual OMR&P	$ 5,415,000	$1,121,059
O&M	$1,425,000	$ 386,915
Replacement	$ 3,990,000	$ 734,144
Total	$ 272,309,285	$258,256,323

Note: OMR&P refers to operation, maintenance, replacement, and power.
Costs are in 2014 dollars. Esclation to the midpoint of construction has been removed.

Table 29. Project Costs and Discounted Present Value, South Tunnel Alternative

Cost Category	Total	Present Value
Field Costs	$237,633,000	N/A
Noncontract Costs	$34,400,000	N/A
Interest During Construction	$14,033,750	N/A
Annual OMR&P	$13,660,200	$3,900,979
O&M	$12,760,000	$3,643,960
Power	$900,000	$257,019
Non-Annual OMR&P	$6,040,000	$1,290,758
O&M	$2,050,000	$556,614
Replacement	$3,990,000	$734,144
Total	$305,766,0750	$291,258,488

Note: OMR&P refers to operation, maintenance, replacement, and power.
Costs are in 2014 dollars. Esclation to the midpoint of construction has been removed.

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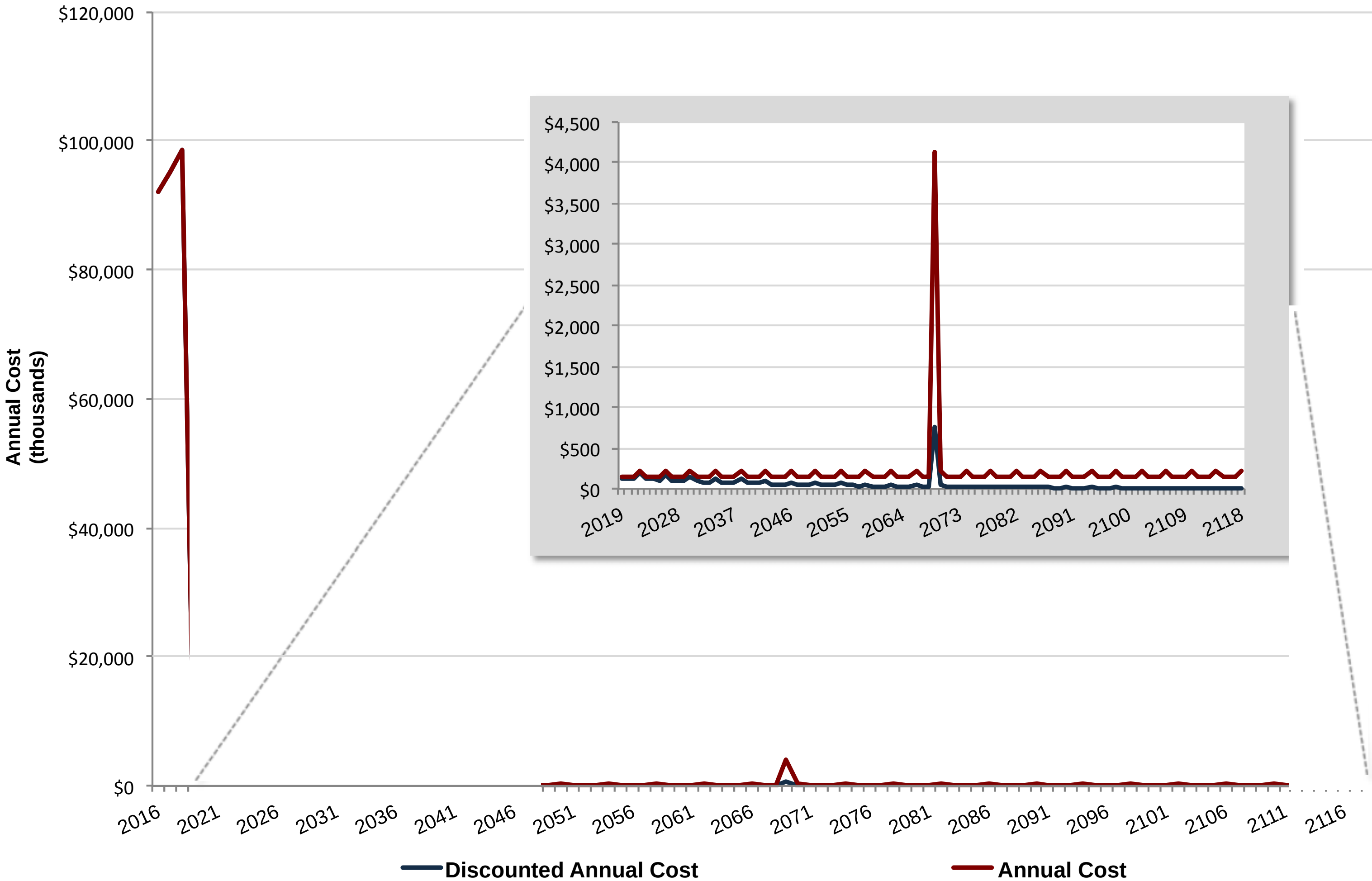

Source: Data from Reclamation and Ecology, 2015d

Figure 14. Project Costs over Time, North Tunnel Alternative

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The total discounted and undiscounted annual costs shown in the tables above include several distinct components:

- **Field costs** are capital and labor costs from procurement to construction closeout. They include mobilization, materials, fabrication, and installation. These capital costs include contract costs, meaning those directly budgeted items, and construction contingencies based upon percentages. They also include allowances for unlisted items and procurement strategies.
- **Noncontract costs** are the additional costs Reclamation and Ecology would incur to complete the design, permitting, construction oversight, and administration before and during the construction process.
- Other ongoing costs include **operations, maintenance, replacement, and power** (OMR&P).

The basis of the cost estimates is modeling but not actual bids, so actual costs are likely to differ. Total costs for the overall Integrated Plan as estimated at the time of the 2012 Four Accounts analysis, updated to 2014 dollars, are 2.8 to 4.5 billion dollars. The KKC costs represent approximately a tenth or less of these total costs.

Costs of BTE Program

Costs of the BTE program are discussed here because Reclamation and Ecology would implement this program in conjunction with the KKC and KDRPP. The agencies estimate Phase 1 of the BTE program would cost $13.3 million in 2014 dollars. Reclamation and Ecology would incur this cost over a 10-year implementation period. Phase 1 includes fish passage improvements at Gold Creek and Cold Creek (tributaries to Keechelus Reservoir); nutrient enhancement at both Keechelus and Kachess Reservoirs; and evaluations of additional physical improvements that Reclamation and Ecology would consider for implementation in a subsequent phase.

3.2.4 Unquantified Costs

Construction and operation of the KKC has the potential to generate other financial and nonfinancial costs. These could include effects such as disruption of access to homes or facilities, or other construction or operational disturbances. The current understanding of the project alternatives suggests little disruption to recreation and related activities attributable to the KKC, as well as little change in Keechelus Reservoir levels both in terms of fluctuations and in long-term reduced levels.

3.3 RED Analysis

The Regional Economic Development analysis utilizes identified expenditures associated with the KKC to identify the value of economic output, the volume of employment, and the amount of income generated by construction and operation of the KKC. The categories of expenditures analyzed under the RED analysis include (1) construction of the KKC, (2) typical annual ongoing expenditures for operating and maintaining the KKC, (3) construction of the BTE Plan, and (4) agricultural activity that occurs because of water made available by the KKC. These impact estimates do not account for how the U.S. Government or taxpayers would use the money associated with these expenditures if the KKC were not constructed. The methodology used is consistent with the *Principles and Guidelines* cited earlier.

The RED analysis is broken down into the four-county immediate region the remainder of Washington State, and the State as a whole. To the extent that Reclamation and the State of Washington would spend these funds within the four-county region without the KKC, the net impacts would be less. However, it is unlikely that Reclamation would spend the same Federal dollars in the four-county region without the KKC, rather than assigning them to water infrastructure projects elsewhere. The variety of competing demands for State spending similarly make corresponding State-level spending unlikely to occur within the four-county region, although some is probable. The irrigation and agriculture impacts though, do likely represent the net impacts for the region. Without the available water supply, fields would not be in production, produce would not be sold, and revenue would not be generated. Residents might spend the small share of final consumer demand for agriculture within the four-county region similarly without the KKC, but the vast majority of these impacts would likely not occur within the region without the water made available by the KKC. That is, the proportion of produce supported by the KKC and consumed locally would be grown elsewhere. Changes in population over time are not incorporated into these analyses, as IMPLAN® data are available for only a snapshot in time, in this case 2012 (the most current available data). Reclamation does not expect the construction, operation, and agriculture effects to change long-term population trajectories for the region.

RED results include the following impact measures as defined within IMPLAN® :

- Output: the sum of expenditures, employee income, proprietor income, profits, and taxes
- Personal Income: total payroll cost of the employees paid by the employer. This includes wages and salary, all benefits (e.g., health insurance, retirement), and payroll taxes (e.g., social security, unemployment taxes)
- Job Years: full-time equivalent jobs over a full calendar year

3.3.1 Expenditure Categories

KKC Construction, Operation, and Maintenance Expenditures

Expenditure categories of construction costs align with IMPLAN® inputs. These expenditures correspond to identifiable costs for the construction period, under both the North Tunnel Alternative and the South Tunnel Alternative (Table 30 and Table 31). Reclamation also identifies the average annual ongoing expenditures for analysis in IMPLAN® of a single representative year upon construction completion (Table 32 and Table 33).

Table 30. KKC North Tunnel Alignment Construction Expenditures

Expenditure Category	Total Expenditures (Millions)
Labor	$81.72
Contractor Overhead and Capital Costs	$124.70
Noncontract Costs	$34.40
Total	$240.81

Table 31. KKC South Tunnel Alignment Construction Expenditures

Expenditure Category	Total Expenditures (Millions)
Labor	$94.08
Contractor Overhead and Capital Costs	$143.56
Noncontract Costs	$34.40
Total	$244.14

Table 32. KKC North Tunnel Alignment Operating Expenditures

Expenditure Category	Total Expenditures of Average Year
Labor	$115,200
Materials and Equipment	$228,000
Total	$343,200

Table 33. KKC South Tunnel Alignment Operating Expenditures

Expenditure Category	Total Expenditures of Average Year
Labor	$115,200
Materials and Equipment	$233,000
Total	$348,200

The total construction impacts for the four-county region, when including indirect and induced expenditures for the construction of the KKC would involve 1,094 to 1,223 job-years and $59.5 to $66.5 million in personal income, depending on the construction alternative (Table 34 and Table 35). For the State as a whole, the value of output would be $270 to $304 million with 1,780 to 2,001 job-years.

The impacts reported in Table 34 to Table 37, and Table 39, only capture those that are not paid for by local contributions. In other words, these impacts do not include the local money that is simply transferred from one group to another within the defined region. For purposes of this analysis, Reclamation and Ecology used an assumption that local entities such as farmers, irrigation districts, or city and county governments participating in the Integrated Plan would pay for 25 percent of capital costs and 100 percent of operating, maintenance, replacement, and power expenses. Actual contribution levels have not yet been determined.

Table 34. KKC North Tunnel Alignment with Option B Construction Impacts, by Type, $ Millions

Region/ Impact Measure	Direct	Indirect	Induced	Total	Multiplier
4 County Region					
Output	$122.5	$12.6	$30.2	$165.2	1.35
Personal Income	$46.9	$3.8	$8.8	$59.5	1.27
Job Years	736	100	258	1,094	1.49
Rest of Washington					
Output	$56.9	$23.1	$24.7	$104.7	1.84
Personal Income	$18.2	$6.5	$7.3	$32.0	1.76
Job Years	380	127	179	686	1.81
Total Washington State					
Output	$179.3	$35.7	$54.9	$269.9	1.51
Personal Income	$65.1	$10.3	$16.1	$91.5	1.41
Job Years	1,116	227	438	1,780	1.60

Table 35. KKC South Tunnel Alignment with Option B Construction Impacts, by Type, $ Millions

Region / Impact Measure	Direct	Indirect	Induced	Total	Multiplier
4 County Region					
Output	$138.1	$13.9	$33.7	$185.7	1.34
Personal Income	$52.5	$4.2	$9.8	$66.5	1.27
Job Years	825	110	288	1,223	1.48
Rest of Washington					
Output	$64.7	$26.2	$27.9	$118.8	1.84
Personal Income	$20.7	$7.4	$8.3	$36.3	1.76
Job Years	431	144	203	778	1.80
Total Washington State					
Output	$202.7	$40.1	$61.6	$304.5	1.50
Personal Income	$73.1	$11.6	$18.1	$102.8	1.41
Job Years	1,256	254	491	2,001	1.59

During a typical year of operation, the KKC would generate approximately 0.4 net additional job-years with total net increases in personal income of $17,309 statewide (Table 36 and Table 37). These annual job-year net increases would last for the life of the KKC.

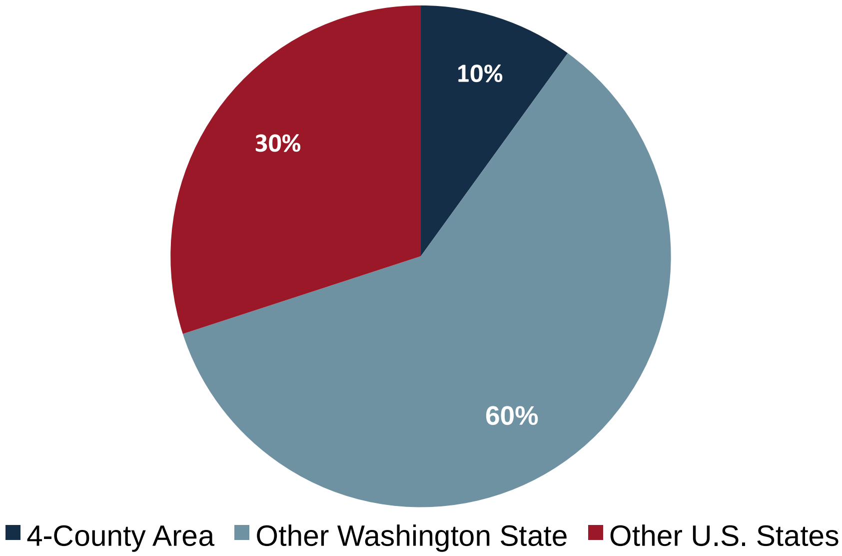
Table 36. KKC North Tunnel Alignment with Option B Operating Impacts, by Type, Rounded

Region / Impact Measure	Direct	Indirect	Induced	Total	Multiplier
4 County Region					
Output	$29,925	$5,731	$7,771	$43,427	1.45
Personal Income	$9,782	$1,848	$2,262	$13,892	1.42
Job Years	0.2	0.0	0.1	0.3	1.54
Rest of Washington					
Output	$0	$8,168	$2,985	$11,153	-
Personal Income	$0	$2,560	$857	$3,417	-
Job Years	0.0	0.0	0.0	0.1	-
Total Washington State					
Output	$29,925	$13,899	$10,756	$54,581	1.82
Personal Income	$9,782	$4,408	$3,119	$17,309	1.77
Job Years	0.2	0.1	0.1	0.4	1.89

Table 37. KKC South Tunnel Alignment with Option B Operating Impacts, by Type, Rounded

Region / Impact Measure	Direct	Indirect	Induced	Total	Multiplier
4 County Region					
Output	$29,925	$5,731	$7,771	$43,427	1.45
Personal Income	$9,782	$1,848	$2,262	$13,892	1.42
Job Years	0.2	0.0	0.1	0.3	1.54
Rest of Washington					
Output	$0	$8,168	$2,985	$11,153	-
Personal Income	$0	$2,560	$857	$3,417	-
Job Years	0.0	0.0	0.0	0.1	-
Total Washington State					
Output	$29,925	$13,899	$10,756	$54,581	1.82
Personal Income	$9,782	$4,408	$3,119	$17,309	1.77
Job Years	0.2	0.1	0.1	0.4	1.89

For purposes of this analysis Reclamation assumed that roughly 10 percent of the capital cost expenditures would accrue in the four-county area, 60 percent would accrue in other Washington State counties, and 30 percent would accrue in other U.S. States (Figure 15). The exact breakdown of these expenditures would depend on the procurement approach and the contractor(s) Reclamation and Ecology select to perform the work. Reclamation would likely draw 100 percent of operation and maintenance labor from the four-county area.



Source: Reclamation and Ecology, 2015d

Figure 15. Assumed Geographic Distribution of Capital Expenditures

Bull Trout Enhancement Plan Construction Expenditures

The BTE Plan would include $13.3 million in expenditures for construction (Table 38). For economic modeling, Reclamation assumed a four-year construction period. These expenditures would generate 59 job-years within the four-county region, 98 job-years for the State as a whole, and $5 million in personal income (Table 39). If Reclamation also constructs the KDRPP, then the KDRPP would share in the BTE impacts.

Table 38. Bull Trout Construction Impacts, Construction Expenditures

Expenditure Category	Total Expenditures (Millions)
Labor	$4.65
Contractor Overhead and Capital Costs	$7.10
Noncontract Costs	$1.55
Total	$13.30

Table 39. Bull Trout Construction Impacts, by Type, $ Millions

Region / Impact Measure	Direct	Indirect	Induced	Total	Multiplier
4 County Region					
Output	$6.7	$0.7	$1.6	$9.0	1.34
Personal Income	$2.6	$0.2	$0.5	$3.2	1.27
Job Years	40	5	14	59	1.48
Rest of Washington					
Output	$3.2	$1.3	$1.4	$5.8	1.84
Personal Income	$1.0	$0.4	$0.4	$1.8	1.76
Job Years	21	7	10	38	1.80
Total Washington State					
Output	$9.9	$2.0	$3.0	$14.9	1.50
Personal Income	$3.6	$0.6	$0.9	$5.0	1.41
Job Years	61	12	24	98	1.59

Agriculture Expenditures

The change in agriculture activity attributable to the KKC alone is negligible, and overly dependent on extrapolation from small scenario differences in YakRW model outputs that are not necessarily accurate and precise. Therefore, ECONorthwest did not estimate economic impacts of the KKC alone. However, when added to the KDRPP, the KKC generates economic activity that produces impacts at substantial levels. This section includes the impact estimates for the share of agriculture activity that the combined KKC and KDRPP Alternative generates beyond the KDRPP Alternative alone.

The basis of these impacts is gross farm earnings as generated with the farm earnings model described in Section 3.2.1. The analysis estimated the impacts attributable to gross farm earnings at each group for each alternative. Then, similar to the calculations to estimate benefits from agriculture production, ECONorthwest developed a weighted average composite across group results for all drought years for each alternative, and calculated the incremental differences between alternatives. The incremental impact of the KKC via the combined KKC and KDRPP alternative relative to the KDRPP alone, under historical climate conditions, results in 212 additional job-years in the four-county region over the 100-year timeframe (Table 40). While the majority of these impacts are experienced in the agriculture sector, they also accrue in transportation and trade (Table 41).

Table 40. KDRPP/KKC Impacts Marginal to KDRPP Alone, Historical Conditions

Region / Impact Measure	Direct	Indirect	Induced	Total	Multiplier
4 County Region					
Output	$16,362,121	$5,820,763	$6,064,918	$28,247,802	1.73
Personal Income	$2,775,840	$2,731,392	$1,698,295	$7,205,526	2.61
Job Years	82	80	50	212	2.61
Rest of Washington					
Output	$0	$1,283,028	$697,535	$1,980,563	-
Personal Income	$0	$218,940	$171,710	$390,651	-
Job Years	0	6	4	10	-
Total Washington State					
Output	$16,362,121	$7,103,791	$6,762,453	$30,228,365	1.85
Personal Income	$2,775,840	$2,950,332	$1,870,005	$7,596,177	2.75
Job Years	82	86	54	222	2.73

Table 41. KDRPP/KKC Impacts Marginal to KDRPP Alone, by Industry, Historical Conditions

Aggregate Industry Sector	Output	Personal Income	Job Years
Agriculture	$18,287,851	$4,743,643	147
Utilities	$231,771	$78,903	2
Construction	$506,507	$203,397	3
Manufacturing	$1,374,565	$102,231	2
Transportation, Information, Utilities	$5,596,194	$1,439,164	41
Trade	$1,455,810	$480,021	14
Service	$399,173	$130,378	3
Government	$395,932	$27,791	0
Total	$28,247,802	$7,205,526	212

Under adverse climate change conditions, the value of the KKC's incremental contributions to KDRPP increase, resulting in 340 job-years in the four-county region with personal income of $11.5 million (Table 42 and Table 43). Since Reclamation expects that droughts will be more frequent under climate change, these incremental effects would occur more often than the effects shown in Table 40.

Table 42. KDRPP/KKC Impacts Marginal to KDRPP Alone Under Adverse Climate Change

Region / Impact Measure	Direct	Indirect	Induced	Total	Multiplier
4 County Region					
Output	$26,480,216	$9,480,249	$9,601,341	$45,561,805	1.73
Personal Income	$4,472,815	$4,371,128	$2,688,583	$11,532,525	2.61
Job Years	134	128	78	340	2.61
Rest of Washington					
Output	$0	$2,161,552	$1,120,105	$3,281,657	-
Personal Income	$0	$362,297	$276,490	$638,787	-
Jobs Years	0	10	7	16	-
Total Washington State					
Output	$26,480,216	$11,641,801	$10,721,446	$48,843,462	1.85
Personal Income	$4,472,815	$4,733,425	$2,965,072	$12,171,312	2.75
Job Years	134	138	85	357	2.73

Table 43. KDRPP/KKC Impacts Marginal to KDRPP Alone Under Adverse Climate Change, by Industry

Aggregate Industry Sector	Output	Personal Income	Job Years
Agriculture	$29,548,428	$7,595,422	236
Utilities	$367,632	$125,151	3
Construction	$820,950	$328,793	6
Manufacturing	$2,242,540	$163,321	3
Transportation, Information, Utilities	$8,964,228	$2,297,599	66
Trade	$2,325,082	$765,829	22
Service	$650,138	$211,274	6
Government	$642,806	$45,136	1
Total	$45,561,805	$11,532,525	340

3.4 EQ and OSE Analysis

Overall, the results for both the EQ and OSE resources are positive for the KKC compared to the No Action Alternative. Since Reclamation would operate the KKC the same regardless of which tunnel alignment is selected, the scoring results are similar for the two action alternatives.

3.4.1 EQ Analysis Results

Table 44 shows that under the No Action Alternative, conditions for most EQ resources would stay the same or decline. This is especially true for instream flows. The KKC would have a moderate positive impact on instream flows and bull trout. Non-listed fish abundance and MCR steelhead would also experience moderate positive impacts. The KKC would provide minor positive impacts to adaptability to climate change. Totals and subtotals in Table 44 may not add up exactly due to rounding.

Figure 16 illustrates that for the EQ resource categories, the KKC provides benefits for the resources that most directly meet the purpose and need for the project -- instream flows, fish, and bull trout. Other EQ resources would experience minor negative impacts with the exception of construction impacts. Significant but temporary negative construction impacts would occur for the KKC as indicated by the significance rating in Table 44. These include travel restrictions, localized traffic congestion on rural roads, and noise, during portions of the three-year construction period.

Table 44. Comparative Display of Alternatives for EQ Categories

EQ Resource Category		Weight	No Action Alternative		KKC North Tunnel		KKC South Tunnel	
			Significance	Score	Significance	Score	Significance	Score
Surface water	Water supply	0.1	-2	-0.2	0	0	0	0
	Instream flows	0.1	-3	-0.3	2	0.2	2	0.2
	Subtotal	0.2		-0.5		0.2		0.2
Bull trout	Food base	0.067	-1	-0.067	1	0.067	1	0.067
	Habitat	0.067	-2	-0.133	2	0.133	2	0.133
	Passage	0.067	-1	-0.067	2	0.133	2	0.133
	Subtotal	0.20		-0.267		0.333		0.333
Fish (not ESA-listed)	Fish abundance	0.1	-2	-0.2	2	0.2	2	0.2
	Fish passage	0.1	0	0	1	0.1	1	0.1
	Subtotal	0.2		-0.2		0.3		0.3
Surface water quality	Reservoir water quality	0.05	0	0	-1	-0.05	-1	-0.05
	Subtotal	0.05		0		-0.05		-0.05
Wildlife	Wildlife	0.05	0	0	1	0.05	1	0.05
	Subtotal	0.05		0		0.05		0.05
Other threatened and endangered species	Northern spotted owl	0.025	0	0	-1	-0.025	-1	-0.025
	MCR steelhead	0.025	-1	-0.025	2	0.05	2	0.05
	Subtotal	0.05		-0.025		0.025		0.025
Recreation	Changed character of recreation	0.05	0	0	-1	-0.05	-1	-0.05
	Subtotal	0.05		0		-0.05		-0.05

EQ Resource Category		Weight	No Action Alternative		KKC North Tunnel		KKC South Tunnel	
			Significance	Score	Significance	Score	Significance	Score
Land use	Property/easement acquisition	0.05	0	0	-1	-0.05	-1	-0.05
	Subtotal	0.05		0		-0.05		-0.05
Cultural resources	Cultural and archaeological resources	0.05	0	0	-1	-0.05	-1	-0.05
	Subtotal	0.05		0		-0.05		-0.05
Climate change	Adaptability to climate change	0.05	-2	-0.10	1	0.05	1	0.05
	Subtotal	0.05		-0.10		0.05		0.05
Construction impacts	Construction impacts	0.025	-1	-0.025	-1	-0.025	-1	-0.025
	Transportation	0.025	-2	-0.05	-3	-0.075	-3	-0.075
	Subtotal	0.05		-0.075		-0.10		-0.10
Totals		1.00		-1.167		0.658		0.658

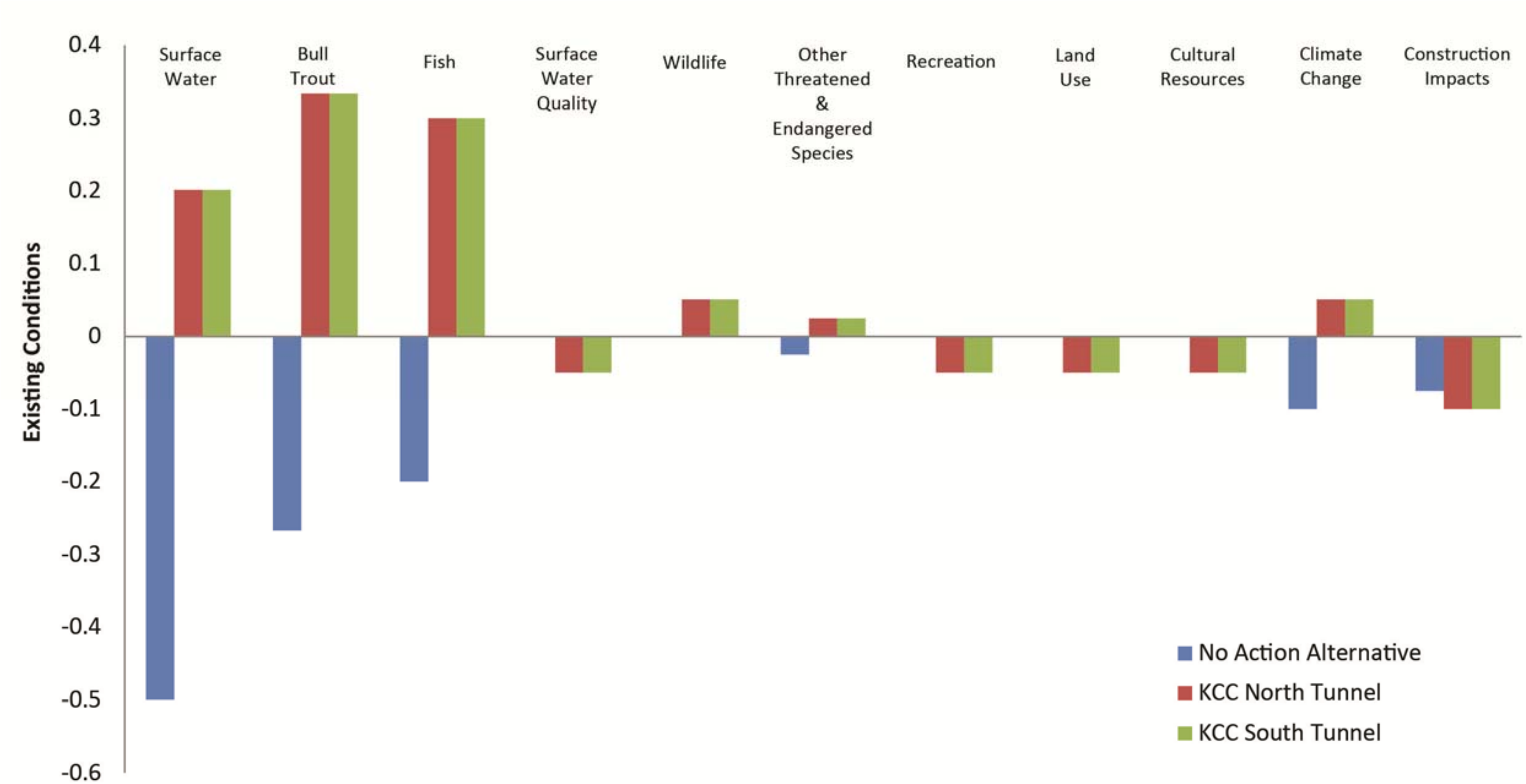


Figure 16. EQ Resource Category Results

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3.4.2 OSE Analysis Results

For the OSE resources, Table 45 shows that the KKC alternatives would have minor negative effects from construction worker impacts and minor to moderate benefits to long-term productivity, whereas the No Action Alternative would have moderate negative impacts on long-term productivity. For Table 45, totals and subtotals may not add up exactly due to rounding. Figure 17 portrays the scoring results graphically. This figure shows that the KKC would have minor negative urban and community impacts.

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Table 45. Comparative Display of Alternatives for OSE Categories

OSE Resource Category		Weight	No Action Alternative		KKC North Tunnel		KKC South Tunnel	
			Significance	Score	Significance	Score	Significance	Score
Urban and community	Construction worker impacts	0.20	0	0.00	-1	-0.20	-1	-0.20
	Subtotal	0.20		0.00		-0.20		-0.20
Long-term productivity	Improved fish populations	0.40	-2	-0.80	2	0.80	2	0.80
	Resilience to climate change	0.40	-2	-0.80	1	0.40	1	0.40
	Subtotal	0.80		-1.60		1.20		1.20
Total		1.00		-1.60		1.00		1.00

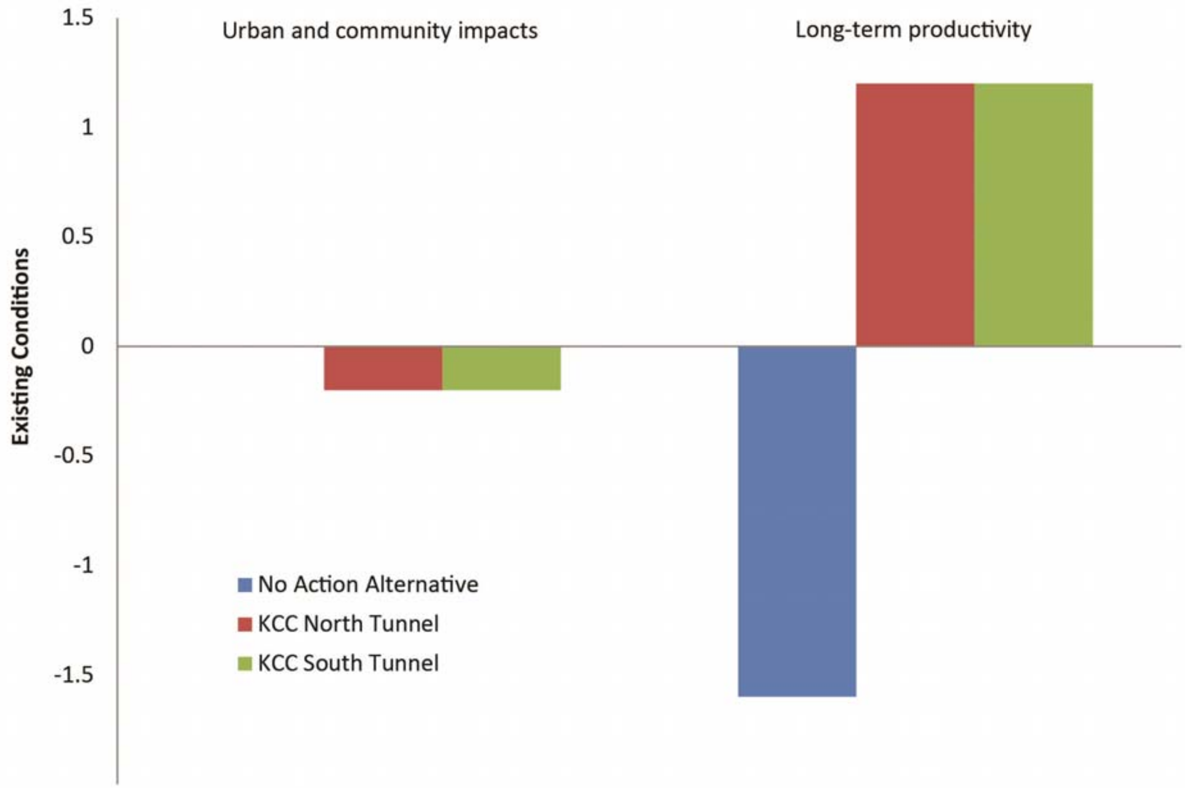

Figure 17. OSE Resource Category Results

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