Statewide Water Needs Assessment

Oregon Water Supply and Conservation Initiative

FINAL

September 2008

Prepared for:

Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem, OR 97301

Prepared by:

HDR Engineering, Inc.
1001 SW Fifth Avenue
Suite 1800
Portland, OR 97204-1134

Participants

Lead Agency

Oregon Water Resources Department

- Phil Ward – Director, Oregon Water Resources Department
- Barry Norris, PE, PLS – Project Manager, State Engineer for Water Resources
- Brenda Bateman, Ph.D. – Senior Policy Coordinator, Director's Office
- Bob Devyldere – Information Services Manager
- Brandi Elmer – Executive Support, Director's Office

Consultants

HDR Engineering, Inc. (Modeling Team)

- Ronan Igloria, PE – Project Manager
- Andrew Graham
- Jerry Louthain
- Joe Miller
- Kelly O'Rourke
- Rona Spellecacy
- Steve Thurin
- Robb Kirkman – Data Manager
- Erik Brewster
- Greg Brink
- James Hagar
- Jason Lemieux
- Ryan Reise

Cogan-Owens-Cogan

- Jim Owens
- Steve Faust

Oregon State University

- Richard Adams, Ph.D.

Technical Peer Review Committee

- Michael Campana, Oregon State University
- Bill McFarland, United States Geological Survey
- Lorna Stickel, Portland Water Bureau

Stakeholder Workshop Partner Organizations

- Association of Oregon Counties
- League of Oregon Cities
- Oregon Association of Clean Water Agencies
- Oregon Environmental Council
- Oregon Farm Bureau
- Oregon Water Resources Congress
- Oregon Water Utilities Council
- Special Districts Association of Oregon

Acknowledgements

The project team would like to thank the many stakeholders – members of water associations, environmental groups, OWRD and other state resource agency staff, local governmental agencies, and legislators – who helped shape, support and secure OWSCI. We would like to especially thank the technical peer review committee for their time: Michael Campana (Oregon State University), Bill McFarland (USGS), and Lorna Stickel (Portland Water Bureau) for their advice and patience; Bruce Fisher (USGS), Jim Johnson and Brent Searle (Oregon Department of Agriculture); and all of the stakeholder workshop partners for their assistance in “spreading the word” to their constituencies to participate in the project.

TABLE OF CONTENTS

Preface vii

Executive Summary ix

Sections

1.0 Introduction and Background 1

1.1 Project Objectives 1

1.2 Planning Parameters 2

1.3 Geographic Breakdown 3

1.4 Demand Forecast Modeling Output 3

1.5 Uncertainty Analysis 5

2.0 Outreach to Water User Groups 9

2.1 Peer Review Committee 9

2.2 Stakeholder Group and Workshops 9

2.3 Survey 10

3.0 Forecasting Model for Out-of-Stream Uses 11

3.1 Model Overview 11

3.2 Forecasting Tool for Out-of-Stream Uses 12

3.3 Model Limitations 13

3.4 Municipal Systems and Domestic Wells 15

3.4.1 Definitions 15

3.4.2 Methodology 15

3.4.3 Data Sources 20

3.4.4 Limitations and Data Gaps 21

3.5 Industrial 22

3.5.1 Definition 22

3.5.2 Methodology 23

3.5.3 Data Sources 23

3.5.4 Limitations and Data Gaps 23

3.6 Irrigated Agriculture 24
3.6.1 Definition 24
3.6.2 Methodology 24
3.6.3 Data Sources for Irrigated Agriculture 26
3.6.4 Limitations and Data Gaps 28
4.0 Statewide Demand Forecast Results 31
4.1 Reference Forecast Results 31
4.1.1 Total Statewide and County-Basin Results 31
4.1.2 Reference Forecast Results - Municipal and Domestic 32
4.1.3 Reference Forecast Results – Self-supplied Industrial 33
4.1.4 Reference Forecast Results – Irrigated Agricultural 33
4.2 Scenario Results for Municipal Systems and Domestic Wells 33
4.2.1 Uncertainty Parameters 33
4.2.2 Base Case Scenario 34
4.2.3 Climate Change and Conservation Scenarios 34
4.3 Scenario Results for Self-Supplied Industrial Water Use 35
4.3.1 Uncertainty Parameters 35
4.3.2 Base Case Scenario 35
4.3.3 Conservation Scenario 35
4.4 Scenario Results for Irrigated Agriculture 36
4.4.1 Uncertainty Parameters 36
4.4.2 Base Case Scenario 36
4.4.3 Climate Change and Conservation Scenarios 36
4.5 Summary of Scenario and Uncertainty Results 37
5.0 Instream Uses 61
5.1 Hydropower 61
5.1.1 Definition 61

5.1.2 Methodology 61

5.1.3 Data Sources 62

5.1.4 Summary of Hydropower Inventory 63

5.1.5 Trends and Issues in Hydropower Demand 65

5.2 Instream Demand for Ecological Needs 66

5.2.1 Definition 66

5.2.2 Methodology 66

5.2.3 Data Sources 71

5.2.4 Results 71

6.0 Future Application and Development 75

6.1 Summary of Findings 75

6.2 Forecasting Tool Modifications and Enhancements 76

6.3 Priority Data Needs 77

6.4 Integration with Water Management Planning Needs 80

7.0 References 81

Tables

Table ES-1. Parameters that can be Adjusted for Scenarios xi

Table ES-2. Total Instream Demand by Administrative Basin (acre-feet) xvi

Table 1. Scenario Summary 4

Table 2. Parameters that can be Adjusted for Scenarios 13

Table 3. Summary of Water Use Classes for the Municipal Systems and Domestic Well Sector 16

Table 4. Public Water Systems (PWS) Used for Developing Per Capita Demands 17

Table 5. "Reference Forecast" from Forecasting Tool – Total Statewide Water Demand (Acre-Feet) 41

Table 6. Change in Forecasted Demand by Counby – Reference Forecast (2010 to 2050) 42

Table 7. Change in Forecasted Demand by Administrative Basin - Reference Forecast (2010 to 2050) 43

Table 8. County Demand by Water Use Category in 2010 and 2050– Reference Forecast (acre-feet) 45

Table 9. Base Case Scenario – Statewide Water Demand (Acre Feet) 47

Table 10. Climate Change Scenarios – Statewide Water Demand (Acre Feet)..... 48

Table 11. Water Conservation Scenario: Statewide Water Demand (Acre Feet)..... 49

Table 12. Summary of Undeveloped Hydropower Potential (taken from INL, 1998)..... 64

Table 13. Instream Demand Ratio for Instream Regions 67

Table 14. Total Instream Demand by Administrative Basin (acre-feet)..... 72

Figures

Figure ES-1. Demand Forecast by Water Use Category – Reference Forecast..... xiv

Figure ES-2. Results of Scenario and Uncertainty Analysis xiv

Figure 1. Oregon Counties..... 7

Figure 2. Administrative Basins – Oregon Water Resources Department 8

Figure 3. Relationship Among Input Data, Forecasting Tool and Uncertainty Analysis..... 14

Figure 4. Components of Forecasting Tool 14

Figure 5. Demand Forecast by Water Use Category – Reference Forecast..... 53

Figure 6. Statewide Total Water Demand Growth for 2050: Distribution by County 54

Figure 7. Municipal Water Demand by County – Reference Forecast (2010) 55

Figure 8. Domestic Well Water Demand by County – Reference Forecast (2010) 56

Figure 9. Self-supplied Industrial Water Demand by County – Reference Forecast (2010)..... 57

Figure 10. Statewide Agriculture Water Demand for 2010: Distribution by County..... 58

Figure 11. Scenario Analysis Comparison of Statewide Demands with Uncertainty Range 59

Figure 12. Grouping of Administrative Basins into “Instream Regions”..... 69

Figure 13. Monthly Instream Demand Ratio for Instream Regions 70

Figure 14. Forecasted Instream Demand for Ecological Use by Administrative Basin – Annual Estimate (acre-feet)..... 73

Appendices

A. Oregon Climate Zones

B. Data Survey and Compilation of Responses

C. Data Processing by Water Use Sector

D. Sample Output from Forecasting Tool

E. Instream Data Processing: Hydropower and Ecological Uses

F. Uncertainty Analysis Workbook

This page intentionally left blank.

Preface

A History – Water Resource Planning in Oregon

As the State of Oregon approaches the centennial of the Oregon Water Act of 1909, water resources planning continues to face multiple and growing challenges – among them ever-increasing demands on limited water supply, water quality limitations, and climate change impacts. In recognizing a need to meet these challenges, the 2007 Legislature provided funds for the Oregon Water Supply and Conservation Initiative (OWSCI). OWSCI represents the first steps to recommit and build on past efforts to manage the state's water resources in a sustainable manner for future generations.

Since adoption of the state's Water Code in 1909, a number of boards, agencies, and bureaus–ranging from the Desert Lands Board to the Willamette Basin Commission–were established to address particular water supply-related issues. In 1955 the Legislative Assembly passed the Groundwater Act extending the regulation of groundwater resources to the area west of the Cascade Mountains. Additionally, the Legislature created the State Water Resources Board, which was given the authority for formulating programs for the use and control of the state's water, and to establish minimum perennial streamflows. Further restructuring of the water agency occurred in 1975 and 1985. In 1975, the State Water Resources Board and the State Engineer's Office were merged to form the Water Resources Department. In 1985, the Water Resources Department was restructured and the Water Resources Commission was created to oversee all activities of the department.

The present-day Water Resources Department was created to enable a more comprehensive and coordinated approach to water policy. The Department's core functions are to protect existing water rights, facilitate voluntary streamflow restoration, increase an understanding of the demands on the state's water resources, provide accurate and accessible water resource data, and facilitate water supply solutions. Over the years, water resource planning efforts targeted an understanding of existing and future demands, and identification of those uses that would be allowed under requests for new water right permits. Recently more emphasis has been placed on finding a balance between competing water interests and facilitation of water supply solutions.

Early water resource planning efforts occurred before 1955 by various boards and agencies, including efforts by the Willamette River Basin Commission in 1945. The focus at that time was on projecting future water needs by category. With establishment of the State Water Resources Board (Board) the legislature directed a coordinated approach to statewide planning and management. The Board was tasked with designating a priority list of present and future water uses. In 1969, the Board completed a study of Oregon's long-range requirements for water designated by use and by basin. Over the next decade or two, documents produced by the Board evolved into what are now referred to as Basin Plans. The plans are fairly comprehensive and provide an index of existing and projected water resource management activities for each basin. Eventually, these Basin Plans were reduced to basin administrative rules and adopted by the Commission. The rules were adopted by basin, with each set of rules unique to that Basin. Basin rules are prescriptive standards whereby new uses may be permitted, and they established minimum streamflows for the protection of aquatic life and water quality.

With the adoption of the Instream Water Rights Act in 1987, the Department was given the authority to establish instream flow levels as certificated water rights. As these instream rights were established, it became apparent that instream needs would be a major component of any future planning effort. Since the Instream Water Rights Act was adopted, the Department has converted more than 500 of the state's minimum perennial streamflows to instream water rights, and has issued more than 900 state agency-applied instream water rights. In addition, Oregon's high priority in planning for present and future instream needs is demonstrated by the fact that Oregon leads the country in flow restoration with more than 1,000 allocations of conserved water, permanent instream transfers, and temporary instream leases that restore about 900 cubic feet per second (cfs) of streamflow for fish and wildlife, recreation, and pollution abatement.

In 1990-1992 the Water Resources Commission adopted as administrative rules the "Oregon Water Management Program." These rules, OAR 690-400-000 through 690-410-080, comprise the Commission's guidance for making general policy decisions related to present and future development of water resources. Perhaps most significant is the water allocation policy that was adopted as part of these rules (OAR 690-410-07). The water allocation policy establishes a requirement that all applications for new water rights be evaluated as to a specific standard for surface water availability. This required evaluation clearly defines the timing and quantity of available surface water for new water rights, and is thereby another significant consideration in any future water resource planning.

In 2002, revisions to rules surrounding water right permit extensions (OAR 690-315) and preparation of water management and conservation plans (WMCP) (OAR 690-086) were adopted. The expansion of the rules provides a process to promote efficient use of the state's water resources and to facilitate water supply planning. A WMCP is a tool that helps water suppliers support applications to OWRD, when water use permits and transfers, reservations of water, and permit amendments are administered. It is a tool the state uses to require water suppliers to implement water conservation measures and plan for future demands.

As the history above chronicles, the state has accomplished much in its attempts to manage water resources effectively. The efforts under OWSCI are intended to provide a set of basic tools that can be used across the spectrum of water resource planning by a broad range of water interests. They are first steps in what promises to be a long-term and comprehensive water resource planning effort.

Executive Summary

This project covers the water needs assessment (demand forecasting) component of the Oregon Water Supply and Conservation Initiative (OWSCI). The Initiative is intended as a first step in what will be the development of a comprehensive plan for meeting future water needs in Oregon. This report documents the data and methodology used in the assessment and presents results from a first-generation water demand forecasting model.

Objectives

The primary objectives of this project are to:

1. Improve OWRD's understanding of the overall magnitude of water demands for various water use categories in different regions across the state.
2. Improve OWRD's understanding of the dynamic trends that affect these uses and how these trends may change in the future.
3. Provide a demand forecasting tool that can be used to examine alternative scenarios affecting future water needs.
4. Determine where key data are missing or inadequate, as well as other sources of uncertainty in water demand forecasting, in order to target available budget resources to improve water planning capabilities.

Planning Parameters

A demand forecast model has been structured that utilizes extensive data on water use, at the appropriate spatial resolution, to assess water demands in a variety of planning scenarios. In this initial effort, the data acquired and the input to the model are relatively limited. The water demand results from this study are limited to statewide, county, and administrative basin levels and cover the time period from 2010 to 2050 in five-year increments.

Water Use Categories Assessed

The forecasting tool was developed for out-of-stream water uses, broken down into four categories:

- Municipal Systems
- Domestic Wells
- Self-Supplied Industrial Uses
- Irrigated Agriculture and Stock Water

For the out-of-stream uses, water "demand" represents the total quantity of water diverted from surface water bodies, or pumped from subsurface aquifers. The study estimates the total quantity pumped or diverted, but does not attempt to differentiate between surface water sources and groundwater sources. A large share of the need defined in this analysis is currently met with

existing supply systems. This study provides a starting point for analysis of how the State's additional future needs can be met through water conservation and supply alternatives.

Instream water uses were analyzed separately, and are considered in two categories:

- *Hydropower* –For the purposes of this study the water demand associated with hydropower is discussed in terms of demand for electricity.

- *Ecological Uses* – instream flow demands for ecological benefit are forecasted using existing instream water rights and scenic water way designations.

A forecast similar to the out-of-stream uses was not generated for these two categories of instream uses; rather a baseline inventory of current demand (or use) was completed.

Demand Forecast Modeling Output

In water resources planning it is useful to explore alternative pathways or future scenarios. Trends from the past may not carry forward into the future. Different observers may have different opinions about the likelihood of certain conditions in future years. For this reason, the demand forecast analysis includes four modeling output results.

The water demand forecast in the forecasting tool is referred to in this study as the "reference forecast."

- The **Reference Forecast** represents a single potential future outcome and the modeling team's "best estimate" using the available information compiled during this study and the team's professional judgment.

In addition, this project provides a scenario analysis to characterize the uncertainty around the data and demand forecast results, as well as to consider two key issues affecting future water demands: climate change and water conservation. Demand forecasts were developed for three alternative scenarios.

- "**Base Case"** scenario extending current water use conditions through year 2050. The base case scenario is used to assess the uncertainty around the demand forecast based on the available data. This is also a useful point of reference for exploring other scenarios developed by users of the forecasting tool.

- **"Climate Change"** scenario reflecting potential shifts in climate patterns based on current climate models. The climate change scenario is used to assess the likely impacts on water demand due to the effects of climate change on key variables.

- **"Conservation"** scenario reflecting the potential for improvements in water-use efficiency. The conservation scenario is used to assess the potential reductions in water demand assuming a range of water conservation savings are achieved over time.

The modeling exercises for the three scenarios (base case, climate change, and conservation) are all uncertainty analyses that illustrate the range of water demands that could occur under the

three scenarios. The uncertainty analysis helps to estimate the effect of data limitations on the initial year estimates. It also assists in analyzing the uncertainty inherent in predicting future conditions that affect water use.

Forecasting Methodology

The methodology built within the forecasting tool uses typical elements of per capita and disaggregated demand models, and employs simple numerical calculations. Table ES-1 summarizes the parameters that can be adjusted in the model and indicates the types of data compiled for the project. The forecasting tool incorporates Visual Basic™ programming code to support interactive use by OWRD staff and/or outside stakeholders. With this tool, users can run their own scenarios for the various water use categories and for any region within the state. The forecasting tool has base data that yield a "reference forecast" for water demand for each of the water use categories (municipal, domestic well, industrial, and irrigated agriculture). The user can either retain the inputs used in the reference forecast, or can modify inputs to construct alternative scenarios.

Table ES-1: Parameters that can be Adjusted for Scenarios

Municipal Systems and Domestic Wells [1]	Self-Supplied Industry [1]	Irrigated Agriculture [1, 2]
• Population in the initial year • Percent change over time (growth rate) • Indoor per capita water use by month • Outdoor per capita water use by month	• Total use in the initial year, by month • Percent change over time	• Irrigated acreage in the initial year • Annual change in acreage, by crop • Consumptive use, by crop • Irrigation efficiency • Conveyance efficiency • Allocation of demands from county to administrative basin (i.e. spatial distribution of irrigated agriculture)

[1] Variables can generally be adjusted either by county or by administrative basin. Variables can generally be adjusted in five-year increments, allowing the rate of change to be adjusted over the 40-year planning period.

[2] Agricultural variables can be adjusted by crop (14 crop groups).

Limitations

As with any model used to describe or predict complex systems, the water demand forecasting tool has limitations. OWRD and outside users should be aware of these limitations in applying results or using the forecasting tool:

- Results from the demand forecasting tool should not be used for detailed planning at the local level. This forecast is at the statewide, county, or administrative basin scale and is not prepared for a small area such as an individual city or irrigation district.

- Because of data limitations the results are best viewed as estimates, particularly in the "first generation" output described in this report.

- Hydropower demands were defined using a review of existing hydropower facilities as a baseline.

- Total instream (ecological) demands were forecasted using existing instream water rights and scenic waterway flows as a base and projecting a similar level of instream need to areas where none is currently defined. Peak flow needs are not within the scope of this project, and will be assessed as part of a planned future analysis on basin yield.

- For purposes of this initial assessment, water needs are estimated as a total quantity, without regard to supply systems or supply constraints.

- Because of software requirements, the capability to do uncertainty analysis was not included in the forecasting tool. The uncertainty analysis was applied only to model runs prepared by the HDR modeling team; however, this capability can be set up for OWRD and other users later, if desired.

Out-of-Stream Demand Forecasting Results

Reference Forecast. The "reference forecast" in the forecast tool represents the "best estimate" forecast by the modeling team under the methodology used in the project. The reference forecast shows an overall increase of ~1.2 million acre-feet annual demand over the 40-year planning period (~1,100 million gallons per day average demand). The majority of the annual demand increase is due to irrigated agriculture (~900,000 acre-feet) followed by municipal (300,000 ac-ft), and domestic well use (50,000 ac-ft). For this study, the industrial demands are considered provisional and projected to remain constant over the planning period because of the limitations on collecting more detailed data. Figure ES-1 shows a graph of the demands by category for the reference forecast. The following points highlight some of the key results based on the reference forecast:

- Counties forecasted to have the greatest increase in municipal water demand through the planning period include Washington, Clackamas, Deschutes, Multnomah, Jackson, Marion, and Lane counties – comprising over 224,000 acre-feet (72%) of the municipal demand increase through 2050. For the domestic well demand, Clackamas, Deschutes, Washington, Jackson, Jefferson, and Lane counties total over 27,000 acre-feet (57%) of the domestic well demand increase in 2050.

- For self-supplied industrial demand, Multnomah, Lane, Columbia, Clatsop, Clackamas, Marion, and Linn counties comprise 62% of the total for this category. Other counties with relatively large self-supplied industrial demands include Coos, Umatilla, Deschutes, and Douglas counties, which comprise 15% of the total demand.

- Counties forecasted to have the greatest increase in agricultural water demand through the planning period include Baker, Harney, Malheur, Umatilla, Morrow, and Lake counties – comprising over 750,000 acre-feet (85%) of the agricultural demand increase through 2050.

Scenario and Uncertainty Analysis. The "reference forecast" is only one potential future water demand outcome. With the uncertainty surrounding each of the input variables, the scenario and uncertainty analysis provides a robust means by which to explore the range of demands that are possible. The base case scenario characterizes the uncertainty in the demand forecast based on

the data and methods used in the model. The changes in agricultural and industrial demands are driven by the uncertainty range defined for the input variables (e.g., irrigated acreage), while municipal demands are driven largely by population growth. By taking account of the uncertainty around the input variables, the increase in total statewide demand can be on the order of 2 million acre-feet under aggressive population growth conditions and increases in irrigated acreage (the increased in demand from reference forecast falls within this range). Figure ES-2 shows how the total statewide demand forecast from the three scenarios compare.

The changes in statewide domestic well demands are significantly smaller than those for the municipal and irrigated agriculture categories. Because irrigated agriculture generally accounts for over 85% of statewide demand, the change in statewide water demand is driven significantly by the amount of irrigated acreage and the types of agricultural water use practices employed. One of the largest uncertainties is associated with self-supplied industrial demand. In general, the type of industry can have the single largest impact on total demand within a county or basin; alternatively, lack of available water to meet the industry's demand can be the single largest constraint to development or growth.

The scenario and uncertainty analysis also considered two key issues affecting future water demand: climate change and water conservation. Even with the assumed parameter constraints and uncertainties with input variables, it is clear that both climate change and water conservation can have drastic effects on water demands. Based on the assumed range of uncertainty under these scenarios, water conservation is shown to have a potentially significant affect on overall water demand. Achievement of this level of conservation would require substantial changes in how the public uses water, as well as significant investments. Furthermore, the county-by-county demands for each sector indicates that those impacts will vary across the state. In the highly agricultural areas in the state, agricultural conservation measures can yield significant reductions in overall statewide demand. In other areas, the impacts between municipal and agricultural conservation will have more balanced benefits. Climate change is also demonstrated to increase the overall demand statewide – although the impacts are smaller relative to the potential from conservation. Climate change was assessed primarily by adjusting the per capita water use factor and crop irrigation requirements. The overall impacts of climate change could also affect other factors such as irrigation season, irrigated acreage and population migration. Taking these factors into account could result in greater impacts on overall demand.

Figure ES-1. Demand Forecast by Water Use Category - Reference Forecast

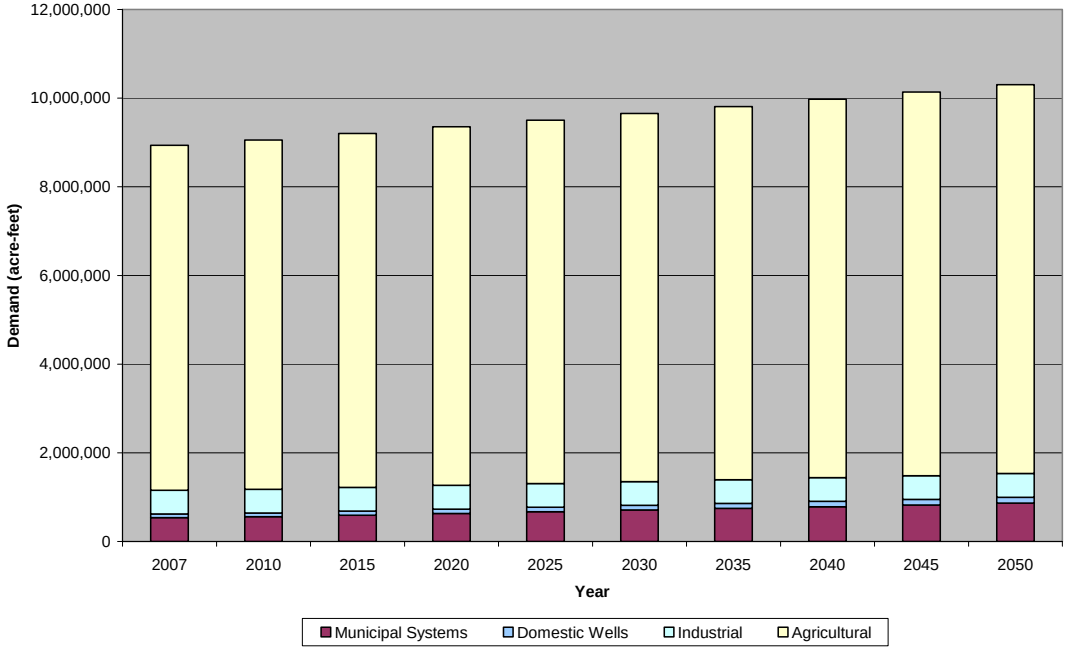
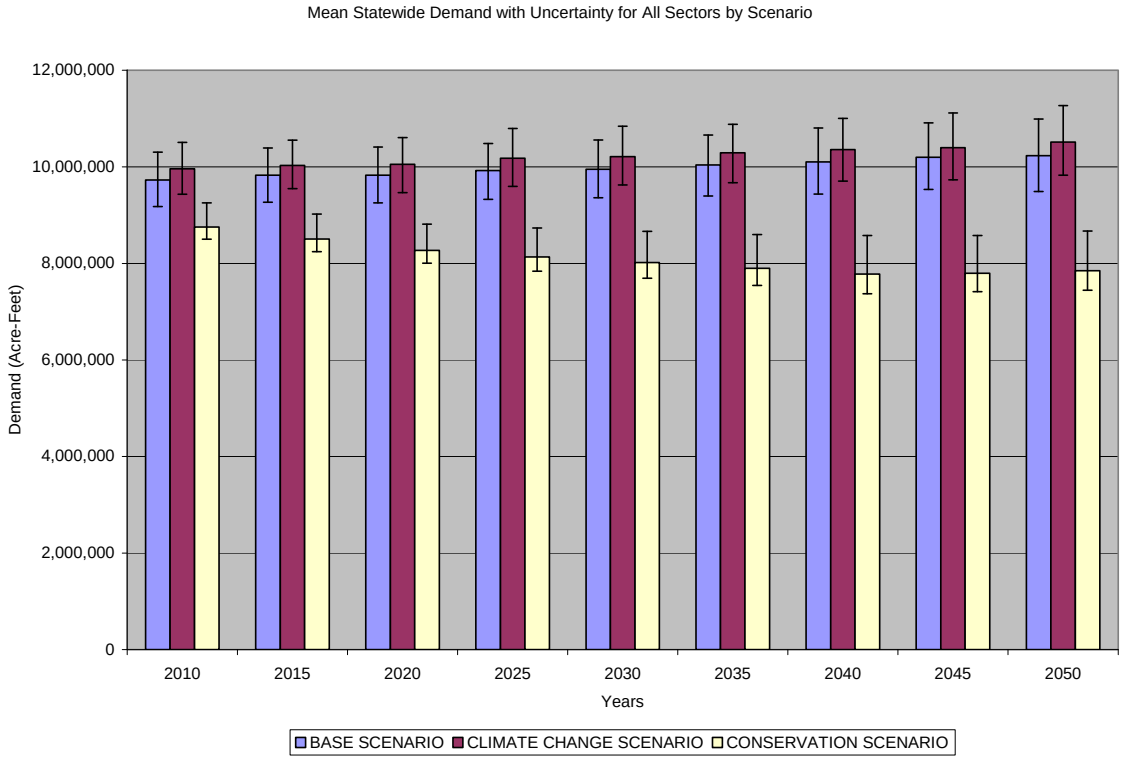


Figure ES-2. Results of Scenario and Uncertainty Analysis



Note: Whisker markers show the range of uncertainty in the demand forecast for each scenario; the whiskers represent the 10th-percentile and 90th-percentile values for demand (e.g. 10th-percentile is the lower whisker bar and is the value with 90 percent probability that demand is higher).

In-Stream Findings

The two instream demands considered in this study include: (i) hydropower and (ii) instream ecological uses. Demands for instream flow are based on an amount of water to be left in the stream as opposed to an amount of water that is removed from the stream for consumptive uses.

Hydropower. Water demand associated with hydropower is directly related to the demand for power (more specifically demand for electricity and/or renewable energy). Hydropower is unique among the water use categories in this project in that regional (or even national) demands impact the state's hydropower demands because of power trading and transmission agreements. Furthermore, while the overall quantity of power demands can be assessed, associating specific projects to meet these demands introduces another order of complexity. For these reasons, the approach taken was to inventory current hydropower facilities related to dams/reservoirs and review qualitative factors that could affect the overall demand for increasing or decreasing hydropower. Furthermore this project focuses on how this energy demand is associated with larger storage projects (1 megawatt of generation capacity) because of their greater impact on stream flow conditions and potential water availability or timing.

The inventory of existing hydropower facilities was extracted from databases maintained by Oregon Water Resources Department and cross-referenced with Federal Energy Regulatory Commission (FERC) data. To account for future hydropower demand, the primary reference is the work that Department of Energy – Idaho National Engineering Laboratory (INL) began in 1998. By assuming that it will be more feasible to expand or add hydropower infrastructure to existing hydropower projects and reservoirs (with or without hydropower), the OWRD databases can be used to identify which administrative basins are more likely to be impacted by expanded hydropower demand in the state.

Based on the INL study, the total name plate capacity based on infrastructure considerations only was estimated to be ~3,500 megawatts of undeveloped capacity, while the adjusted capacity to account for environmental constraints was estimated to be ~2,200 megawatts. This is in comparison with a net capacity over 8,300 megawatts of conventional hydroelectric power generation capacity in 2006. Based on the inventory of hydroelectric facilities and large reservoir projects, most of the facilities considered to have the highest potential to meet demands for new or additional hydropower are located in the Willamette, Umpqua, Rogue, Deschutes basins. There are also limited number of facilities in Sandy, Owyhee, Hood, Umatilla, and Wallowa basins.

Instream Demand for Ecological Use. For the purposes of estimating instream demand for this project, instream flow demands are forecasted using existing instream water rights and scenic water way designations. Where water availability basins do not have an instream water right or other established flow requirement, a forecast of instream flow need is made using a fraction (or ratio) of the 50% exceedance natural flow levels in the same region. The fraction for each WAB is found by dividing the established instream water right by the 50% exceedance flow for each month.

The administrative basins are grouped into the following four instream regions:

- Coastal Region: Basins 1, 17 and 18
- Western Interior Region: Basins 2, 3, 15 and 16
- Central Region: Basins 4, 5, 6, and 14
- Eastern Region: Basins 7, 8, 9, 10, 11, 12 and 13

The total instream demand on a volumetric basis is determined for each administrative basin by summing the contribution at each discharge point within the basin ("pour point"). The results for the annual total, July and January months are shown in Table ES-2, which also shows the out-of-stream demand for 2010 based on the reference forecast in the forecasting tool.

The Willamette Basin has the largest instream annual demands based on this method with over 11 million acre-feet annually. The coastal basins, Deschutes Basin, Rogue, Umpqua, and Klamath basins have the next highest annual instream demands on the order of one to four million acre-feet. The eastern basins have significantly less – typically with less than one million acre-feet annually. Because of the different streamflow patterns in the basins, the ratio of the July to January instream demands are typically lowest in the wetter basins and highest in the eastern or drier basins. The smaller the percentage or ratio implies a smaller instream demand in the summer than in the winter.

Table ES-2. Total Instream Demand by Administrative Basin (acre-feet)

Administrative Basin	Annual	July	January	Ratio July/Jan	Annual Out-of-stream Consumptive Demand (2010)*	Annual Ratio (out-of-stream/ instream)
1 - North Coast	4,214,000	86,000	668,000	13%	620,000	14%
2 - Willamette	11,560,000	370,000	1,578,000	23%	2,558,000	22%
3 - Sandy	915,000	44,000	98,000	45%	38,000	4%
4 - Hood	670,000	38,000	79,000	48%	338,000	50%
5 - Deschutes	2,772,000	219,000	225,000	97%	232,000	8%
6 - John Day	794000	30,000	48,000	62%	966,000	119%
7 - Umatilla	459,000	15,000	48,000	32%	350,000	75%
8 - Grande Ronde	1,521,000	119,000	85,000	140%	207,000	13%
9 - Powder	575,000	40,000	28,000	143%	863,000	146%
10 - Malheur	203,000	8,400	11,000	73%	246,000	121%
11 – Owyhee**	N/A	N/A	N/A	N/A	62,000	N/A
12 - Malheur Lake	230,000	11,000	12,000	91%	70,000	31%
13 - Goose & Summer Lake	248,000	9,700	12,000	78%	51,000	21%

Table ES-2. Total Instream Demand by Administrative Basin (acre-feet)

Administrative Basin	Annual	July	January	Ratio July/Jan	Annual Out-of-stream Consumptive Demand (2010)*	Annual Ratio (out-of-stream/ instream)
14 - Klamath	1,033,000	83,000	90,000	92%	780,000	75%
15 - Rogue	3,324,000	124,000	402,000	31%	974,000	29%
16 - Umpqua	3,064,000	86,000	442,000	19%	46,000	1%
17 - South Coast	4,096,000	69,000	655,000	10%	566,000	14%
18 - Mid Coast	3,860,000	82,000	622,000	13%	90,000	2%

** Based on the reference forecast in the forecasting tool.*
*** Owyhee Basin does not have a separate forecasted instream demand because its discharge point (pour point) is to the Malheur Basin. The forecasted instream demand for Malheur Basin includes Owyhee Basin. There are no existing instream water rights defined for Owyhee Basin.*

It was agreed by the state agencies that peak flow considerations would not be included in this phase of the OWSCI demand assessment for instream flows. It was agreed that peak flow considerations are applicable on a stream-by-stream basis and not appropriate for the basin-scale assessments and policy-level planning comparisons under this phase of the OWSCI project. OWRD plans to incorporate instream peak flow demands as part of a planned basin yield analysis.

Data Limitations and Future Applications

One of the objectives of the project was to determine where key data are missing or inadequate, and to identify sources of uncertainty in water demand forecasting, in order to target available budget resources to improve water planning capabilities. The following recommendations are related to the key priority data needs as well as other relevant studies that have been identified to help improve the state's water planning capabilities.

- ***Enhance OWRD's water use reporting system.*** This recommendation integrates the key data gaps (data limitations listed in Section 3) with the need to develop an efficient process to collect and process the information. OWRD already has a program through the water use reporting system that can be enhanced to include appropriate data used in the forecasting tool, as well as for general water planning capabilities.
    - Continue outreach to water providers and stakeholders to increase participation in the water use reporting process to support forecasting updates; more complete water use information from all sectors will reduce the uncertainty surrounding the input variables of the model.
    - Develop a standardized and streamlined data transfer system to make data collection process practicable for both OWRD and the water users.
    - Leverage and support the work by USGS to compile water use information; consider developing a similar and parallel process for Oregon that compiles information for the same major water use categories.

- ***Conduct a study on trends in irrigated agriculture for the state.*** A robust and sophisticated economic analysis is needed to derive trends in irrigated agriculture. This would improve the estimates and basis for the agricultural water demand.
- ***Study urban-rural development patterns.*** This study would focus on analyzing the development patterns and trends with respect to urban and rural densities and transition of agricultural land to urban and rural development which might impact water demands.
- ***Develop a coordinated population forecasting program for the state.*** Population growth rates are desirable on a smaller geographical scale to allow for more reliable population estimates at the scales used in the forecasting tool. A coordinated population forecasting program could be used to provide input on a scale such as the census block group or other smaller geographic unit.
- ***Conduct a water use study for the self-supplied industrial sector.*** A detailed study on water use by different types of self-supplied industries would greatly improve the estimates and basis for the industrial demand.
- ***Conduct a statewide water conservation potential assessment.*** A statewide CPA would provide a more quantitative basis for estimating how much water savings could be achieved with a variety of conservation best-practices. This study is different than – but would enhance – the conservation inventory project conducted under OWSCI, which focused on collecting information on planned future projects. Information on conservation measures from water management and conservation plans required under Division 86 rules can be used as a starting point for estimating conservation potential.
- ***Conduct a study on local climate change impacts for the state.*** There is a need to "translate" global and large-scale regional models to climate zones within the state. Information from these and future studies should be integrated into the forecasting analysis.
- ***Complete hydrological study for ecological needs.*** This series of studies would be conducted for each administrative basin and include hydrological analysis of basin water yield. The studies could be done in conjunction with studies for instream flows, including peak flow analysis, for ecological needs. The instream flow studies would have to be conducted in specific reaches across the state to refine the methodology used in this study.
- ***Conduct a hydropower potential assessment.*** A more focused and comprehensive market assessment for hydropower is needed to estimate the water demand associated with different hydropower categories for existing and new reservoir/storage facilities, installing new hydropower in existing facilities, and other infrastructure (e.g. micro-hydro in canals and pipelines).
- ***Study to evaluate sources of supply.*** As a follow-on to the water demand focus of this study, there is a need to assess how water demands are being met by current sources of supply across the state (including water conservation). By understanding both the demands and supplies, the state can examine the source of supply deficiencies for planning and management purposes.

Summary of Conclusions

The objectives of this project were to gain a better understanding of the water demands in the state, develop tools for assessing water demands, and identify data needs and next steps to improve water planning capabilities. Key findings from the project include:

- The out-of-stream demands in the state are projected to increase significantly over the next 20 and 50 years, driven by continuing demands from agriculture, population growth, and industry. An increase of over 1 million acre-feet annual water demand is forecasted over the next 40 years based on the reference forecast.

- Irrigated agriculture currently accounts for the greatest demands statewide with over 85% of the overall out-of-stream demand, as well as accounting for ~75% of the forecasted increase in demand over the next 40 years. Baker, Gilliam, Grant, Harney, Morrow, Sherman, and Umatilla counties in particular have the potential to see the most significant increases in agricultural water demands.

- Population growth is expected to be the key driver for increasing municipal water demand in several key counties, including Clackamas, Deschutes, Josephine, Lincoln, Polk, Washington, and Yamhill counties.

- Water conservation can significantly reduce water demands in all water use categories. Using fairly aggressive conservation assumptions, total water savings of approximately 25% can be realized when comparing the reference forecast to the mean forecast for the conservation scenario. On average this is equivalent to achieving a water savings of 0.6% per year over the next 40 years. It should be noted that achievement of this level of conservation would require substantial changes in how the public uses water, as well as significant investments, i.e., funding to support infrastructure and management improvements.

- The climate change scenario modeled is preliminary in nature and additional study is needed to understand its impacts on a local and regional basis. For this study, climate change was assumed to have a moderate to fairly extreme effect on water use factors (i.e., increase of 8-18% on average on outdoor per capita water use and irrigation requirements over 40 years). The analysis results indicate less than 3% increase in the average demand when comparing the reference forecast to the mean forecast for the climate change scenario. Nevertheless, climate change is considered an important factor in how future water demands unfold because of the uncertainty it poses on overall water demands in all of water use sectors – especially on agricultural demands.

- The findings from the demand forecast scenarios and the forecasting tool are useful for estimating the current magnitude and distribution of water demands, and understanding general trends for the purposes of policy discussions. However, the data gaps highlighted in this study indicate the need to understand the limitations of the model and the uncertainties associated with the demand forecast.

As OWRD proceeds with OWSCI, the Department will work with water users, stakeholders and the Legislature to determine how the water needs assessment documented in this report can best be coordinated with water supply planning activities. Additional questions will undoubtedly be identified that can be addressed, in part, through additional attention to the water needs assessment.

1.0 Introduction and Background

Oregon Water Resources Department (OWRD) received funding from the Oregon Legislature in 2007 to conduct the Oregon Water Supply and Conservation Initiative (OWSCI). The Initiative is intended as a first step in what will be the development of a comprehensive plan for meeting future water needs in Oregon.

OWSCI has five main components:

1. A compilation of already-existing information regarding water demands and needs in Oregon;
2. A statewide inventory of already-identified, potential conservation projects;
3. A statewide inventory of potential storage sites;
4. Match funding for community-based and regional water supply planning;
5. Completion of a state investigation of basin yield estimates (unfunded by State).

This report covers the first component: water demands and needs in Oregon. OWRD retained HDR Engineering to develop a State/Regional Water Needs Assessment. The report documents the data and methodology used in the assessment and presents results from a first-generation water demand forecasting model.

1.1 Project Objectives

The primary objectives of this project are to:

1. Improve OWRD's understanding of the overall magnitude of water demands for various water use categories in different regions across the state.
2. Improve OWRD's understanding of the dynamic trends that affect these uses and how these trends may change in the future.
3. Provide a forecasting tool that can be used to examine alternative scenarios affecting future water needs.
4. Determine where key data are missing or inadequate, as well as other sources of uncertainty in water demand forecasting, in order to target available budget resources to improve water planning capabilities.

A demand forecast model has been structured that accommodates extensive data on water use, at the appropriate spatial resolution, to assess water demands in a variety of planning scenarios. In this initial effort, the data acquired and the input to the model are relatively limited. The reported geographic scales are limited to statewide, county, and administrative basin levels. The basic data and modeling approach used was designed to permit expanded and updated data to be input as OWRD continues with the OWSCI and related activities. The model can be modified to permit alternative geographic breakdowns.

1.2 Planning Parameters

The State/Regional Water Demand Model covers the time period from 2010 to 2050 in five-year increments. A spreadsheet tool was developed for out-of-stream water uses, broken down into four categories:

- Municipal Systems
- Domestic Wells
- Self-Supplied Industrial Uses
- Irrigated Agriculture and Stock Water

For the out-of-stream uses, water "demand" represents the total quantity of water diverted from surface water bodies, or pumped from subsurface aquifers. While much of this water is delivered to actual users, some is not. Depending on the type of system used to extract, convey and deliver water, some of the water may be lost to seepage, leakage or evaporation. Some of it passes unused through user facilities and is returned to the environment as return flows, or discharges through wastewater treatment plants or septic systems. Through these processes, some of the water pumped or diverted eventually returns to aquifers and surface water bodies at other locations to support stream flow or become available again for other users. These relationships can be highly complex and variable among different water-use systems. The current study does not attempt to segregate water into different end points. Instead, the study estimates the total quantity pumped or diverted. Likewise, the study does not attempt to differentiate between surface water sources and groundwater sources.

For purposes of this initial assessment, water needs are estimated as a total quantity, without regard to supply systems or supply constraints. A large share of the need defined in this analysis is currently met with existing supply systems. This study provides a starting point for analysis of how the State's additional future needs can be met through water conservation and supply alternatives.

Instream water uses were analyzed separately, and are broken down into two categories:

- *Hydropower* – For the purposes of this study the water demand for hydropower is discussed in terms of the demand for hydropower. The approach here is to inventory current hydropower facilities related to dams/reservoirs and review qualitative factors that could affect the overall demand for increasing or decreasing hydropower.

- *Ecological Needs* – Instream flow demands for ecological benefit are forecasted using existing instream water rights and scenic water way designations. Where basins do not have an instream water right or other established flow requirement, the forecast of instream flow need is made using a fraction (or ratio) of median natural flow levels.

A forecast similar to the out-of-stream uses was not generated for these two categories of instream uses; rather a baseline inventory of current demand (or use) was completed.

Water Use Categories Defined for Statewide Water Needs Forecast

1.
Out-of-Stream Uses
(additive)

A.) Municipal Systems
+
B.) Domestic Wells
+
C.) Self-supplied Industry
+
D.) Irrigated Agriculture & Stock Water

2.
Instream Uses
(not additive)

A.) Hydropower

B.) Ecological Needs

1.3 Geographic Breakdown

Much of the analysis performed for this study was designed to accommodate various geographic breakdowns. Results are generally reported using three geographic categories: statewide, county, and administrative basin totals. Figure 1 and Figure 2 display counties and administrative basins in the State of Oregon.

1.4 Demand Forecast Modeling Output

In water resources planning it is useful to explore alternative pathways or future scenarios. Trends from the past may not carry forward into the future. Different observers may have different opinions about the likelihood of certain conditions in future years. For this reason, the demand forecast analysis includes four modeling output results.

The water demand forecast in the forecasting tool is referred to in this study as the "reference forecast."

- The **"Reference Forecast** represents a single potential future outcome and the modeling team's "best estimate" using available information compiled during this study and best professional judgment.

In addition, this project provides a scenario analysis to characterize the uncertainty around the data and demand forecast results, as well as to consider two key issues affecting future water demands: climate change and water conservation. Demand forecasts were developed for three alternative scenarios.

- "**Base Case"** scenario extending current water use conditions through year 2050. The base case scenario is used to assess the uncertainty around the demand forecast based on the available data. This is also a useful point of reference for exploring other scenarios developed by users of the forecasting tool.

- **"Climate Change"** scenario reflecting potential shifts in climate patterns based on current climate models. The climate change scenario is used to assess the likely impacts on water demand due to the effects of climate change on key variables.

- **"Conservation"** scenario reflecting the potential for improvements in water-use efficiency. The conservation scenario is used to assess the potential reductions in water demand assuming a range of water conservation savings are achieved over time.

The modeling exercise for the three scenarios (base case, climate change, and conservation) includes an uncertainty analysis to illustrate the range of water demands that could occur under the three scenarios. The uncertainty analysis helps to estimate the effect of data limitations on the initial year estimates. It also assists in analyzing the uncertainty inherent in predicting future conditions that affect water use. Further information on these three scenarios is shown in Table 1.

Table 1. Scenario Summary

Forecast Input Variable	Base Case Scenario	Climate Change Scenario	Water Conservation Scenario
Municipal and Domestic Wells			
Population Growth Rate	Base estimate from data	Same as baseline	Same as baseline
Per Capita Water Use	Base estimate from data	Increased per capita outdoor use	Decreased total per capita use
Self-Supplied Industry			
Water Use by County	Base estimate from data	Same as baseline	Decreased total use
Agricultural			
Irrigated Acreage	Base estimate from data	Same as baseline	Same as baseline
Consumptive Use	Base estimate from data	Increased consumptive use factor	Same as baseline
Irrigation Efficiency	Uniform assumed value	Same as baseline	Increased efficiency
Conveyance Efficiency	Uniform assumed value	Same as baseline	Increased efficiency
Monthly Water Use Pattern	Uniform assumed value	Uniform assumed value	Uniform assumed value

Actual future conditions may represent some combination of the three scenarios described above. Collectively these scenarios help to illustrate a range of possible changes in demand that could occur. The model is structured to permit users to run additional scenarios reflecting a wide spectrum of possible future conditions. For example, for the purposes of this study monthly water use patterns were assumed not to change among the scenarios evaluated, but the model includes this variable because it can be an important issue in evaluations of water availability and timing.

The forecast results in Section 3 are discussed in terms of the reference forecast, as well as the uncertainty range of demands developed under the scenario analysis. The "reference forecast" and scenario analysis results allow OWRD to better understand the overall magnitude of water demands across the state, as well as the uncertainty around the demand forecast. The forecasting

tool also allows OWRD and other stakeholders to evaluate other future scenarios and to better understand data needs for refining forecasting capabilities.

1.5 Uncertainty Analysis

An uncertainty analysis was performed to illustrate the range of water demands that could occur. The uncertainty analysis helps to estimate the effect of data limitations on the initial year estimates. It also assists in analyzing the uncertainty inherent in predicting future conditions that affect water use. Finally, it illuminates which variables make the greatest difference in terms of uncertainty. With this information, analysts can target those variables for further research to improve forecasts.

The uncertainty analysis runs within the same model that is used for the basic forecasting exercise. However where the spreadsheet forecasting tool (described in Section 3.2) uses a single value for each variable to calculate a single outcome, the uncertainty analysis runs a range of values to yield a range of outcomes. This process is carried out using a procedure known as "Monte Carlo" simulation that is widely used by economists and other analysts to analyze risk and uncertainty.

The Monte Carlo simulation runs the model calculations numerous times, for hundreds or thousands of iterations. Each time it selects values for each variable randomly from a pre-specified distribution. Values that are defined as more probable within the distribution will be selected more frequently than values defined as less probable. Furthermore, the uncertainty in the demand output associated with the combined uncertainty of all of the input variables are accounted for. During each iteration, the model outcome (i.e., demand forecast) is calculated independently. The model outcomes can then be displayed as a range. A probability can be associated with each value in the range of outcomes.

Inputs to the uncertainty analysis include:

- Selection of specific variables to be varied in the simulations. These are the same variables used in the model, or a subset of those believed to be most significant in terms of uncertainty.
- Definition of a probability distribution for each variable selected. For the analysis conducted, the distribution was defined by a high, medium, and low expected value of each variable, and a probability associated with each of these. The probability distributions were defined by the modeling team based on assumptions documented in **Appendix F**.
- For values expected to change over time, the range of values was expanded between 2010 and 2050. This reflects the understanding that those variables with a trend will diverge further from current conditions, and we are more uncertain about conditions farther out in the future.

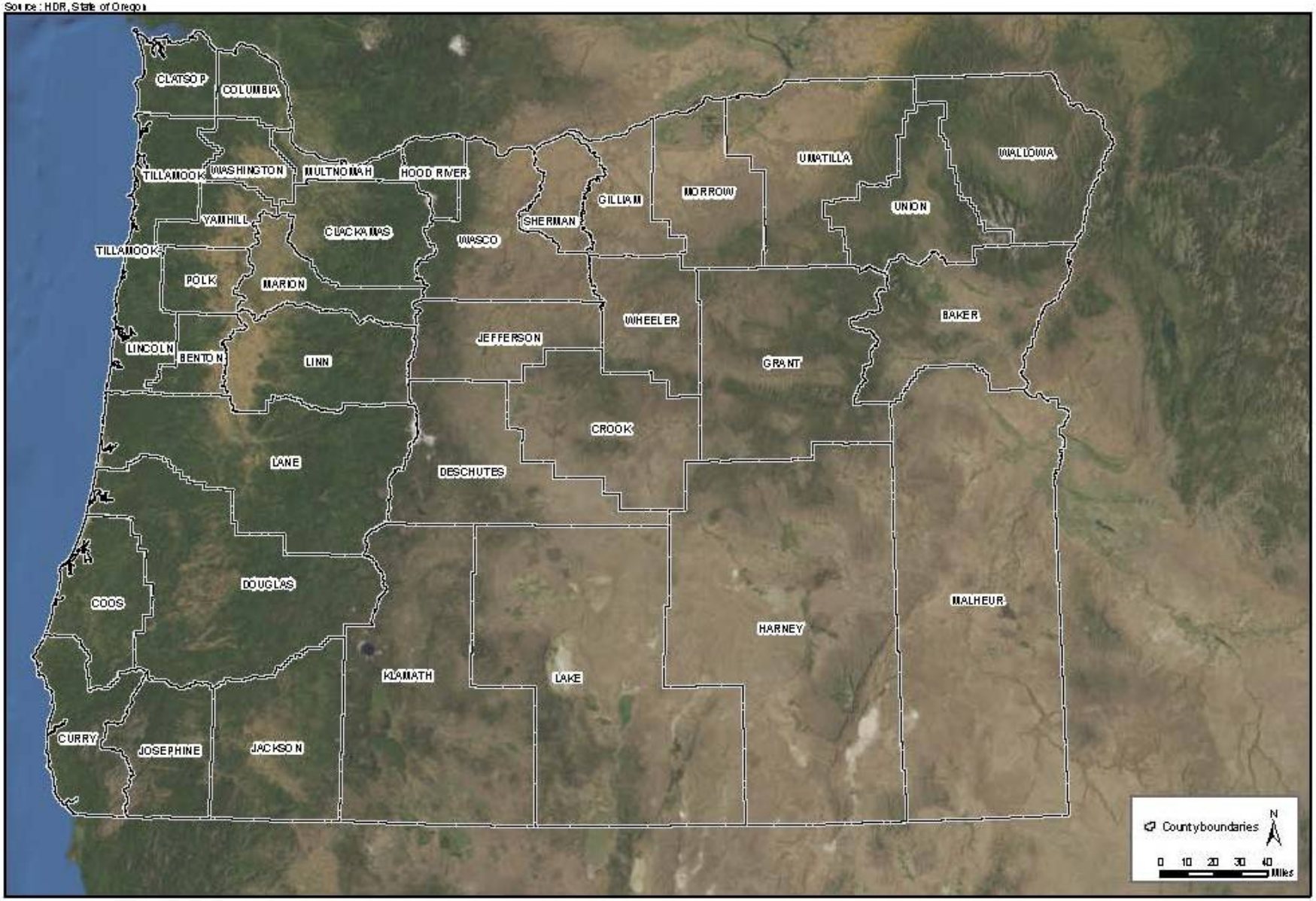
The uncertainty analysis is discussed further in Section 3 where the demand forecast for each water use category is described. In addition, information on specific variables and the ranges of

values used in the uncertainty analysis is contained in **Appendix F**. The outcomes are reported in Section 4 of this report.

The remainder of this report describes the data and methodology used in developing the forecasting model, and provides results from the initial runs of the model (reference forecast based on the data in the spreadsheet model and the range of demands developed under the uncertainty analysis).

OWRD intends to make the forecasting model available for use by interested parties, and anticipates continued refinement of input data and output results.

Source: HDR, State of Oregon



Oregon Counties

FIGURE 1

HDR
ONE COMPANY | Many Solutions

Source: HDR, State of Oregon

OWRD Administrative Basins
FIGURE 2

HDR
ONE COMPANY | Many Solutions

2.0 Outreach to Water User Groups

An outreach plan developed at the beginning of the project focused on four primary elements: (1) Peer Review Committee; (2) Stakeholder Group and workshops; (3) survey; and (4) interviews.

2.1 Peer Review Committee

A peer review committee of technical experts was convened by OWRD to:

- Advise on outreach to water-related associations, water users/providers, and others.
- Review/advise on project methodology and process.
- Review/advise on draft and final products.
- Advise on next steps in developing a comprehensive statewide water supply plan.

The committee met at three key junctures in the planning process: in February 2008 to review the project methodology; in April 2008 to be briefed on the status of the project and survey responses and to advise on strategies to increase survey response; and in August 2008 to review and comment on the findings of the demand forecast.

Members of the Peer Review Committee included:

- Michael Campana, Oregon State University
- Bill McFarland, United States Geological Survey
- Lorna Stickel, Portland Water Bureau

2.2 Stakeholder Group and Workshops

A series of four workshops around the state were conducted to inform water users about OWSCI and how the two project fits into it, obtain input on proposed methodologies and data collection efforts, and respond to questions about the survey and the use of the data obtained.

Date	Location	Attendees[1] (#)
March 4, 2008	Salem, OR at OWRD Offices	38
March 7, 2008	Medford, OR at Old Jackson County Courthouse	18
March 18, 2008	Redmond, OR at Redmond Library	20
March 19, 2008	Pendleton, OR at City Hall	28

(1) Based on the number of attendees signing the sign-in sheet.

To ensure broad notification and encourage participation, the workshops were co-sponsored by the Association of Oregon Counties, League of Oregon Cities, Oregon Water Resources Congress, Oregon Water Utilities Council, Special Districts Association of Oregon, Oregon Farm Bureau, and Oregon Association of Clean Water Agencies. Notification was provided in

conjunction with the survey; through flyers, media releases, and publication in organization newsletters; and on OWRD's website. The associated workshop materials are included in **Appendix B**.

2.3 Survey

Beginning in March 2008, a survey was distributed to collect data about water use and water demand in the municipal and agricultural sectors. The survey was designed to provide data for use in developing the water demand forecasting model.

Beginning in early March, 2008, the survey was distributed at workshops and other events to OWRD's database of water users, and by workshop co-sponsors to their member organizations and utilities. Through a "Survey Monkey" program (on-line survey response program), several options were provided to complete the survey online, including the full survey, municipal water use data section only, agricultural water use data section only, or inventory of Conservation Opportunities section only. An April, 2008 letter from the department's Director was distributed to water users, irrigation districts, and other key parties encouraging responses to the survey.

A compilation of survey responses is included in an electronic spreadsheet file provided to OWRD. The survey was completed by 96 water user and stakeholder groups.

3.0 Forecasting Model for Out-of-Stream Uses

3.1 Model Overview

As described above, the State/Regional Water Demand Model covers the time period from 2010 to 2050 in five-year increments. A spreadsheet tool was developed for out-of-stream water uses. The spreadsheet tool applies a different set of data, assumptions, and calculations to each of the following categories of water use:

- Municipal Systems
- Domestic Wells
- Self-Supplied Industrial Uses
- Irrigated Agriculture and Stock Water

Various techniques are used in the water resources field to forecast water needs. These include simple planning models (e.g. "per capita" models) that extrapolate demand based primarily on population growth while holding other factors constant; more advanced "disaggregated numerical models" that examine water use sectors separately and permit different assumptions about future conditions; and advanced econometric (statistical) methods using multiple regression techniques.

This project combines elements of per capita and disaggregated demand models, and employs simple numerical calculations developed in the spreadsheet tool. There were several reasons for this choice:

- A relatively simple methodology was selected to keep data collection and processing requirements feasible within project budget constraints. This enabled the inclusion of the full set of water uses (municipal, domestic, industrial, and agricultural) and to apply the forecast at the statewide geographic scale.
- Econometric techniques require more extensive data collection and data processing. Such methods are more appropriate to situations where data inputs are more consistent or can be more carefully controlled, such as detailed studies of a single water-use category.
- Simple numerical calculations can be reviewed and evaluated easily. Inputs and assumptions can be readily documented and explained. Compared with econometric methods, this makes the model more "transparent" to agency staff or stakeholders who are not trained in advanced modeling techniques.
- A spreadsheet tool applying numerical calculations offers the capability for OWRD and outside users to run alternative scenarios easily, applying different assumptions from those used to prepare the baseline forecast.

This methodology is well-suited to achieving the objectives outline in Section 1 of this report.

3.2 Forecasting Tool for Out-of-Stream Uses

As part of this project, HDR Engineering, Inc. developed a forecasting tool ("forecasting tool") covering out-of-stream water uses for OWRD. The "State/Regional Water Demand Model" was delivered as a fully functional digital file. The forecasting tool incorporates Visual Basic™ programming code to support interactive use by OWRD staff and/or outside stakeholders. With this tool, users can run their own scenarios for the various water use categories and for any region within the state. This section summarizes the content and functions of the forecasting tool.

Figure 3 shows how the forecasting tool relates to the input data, forecasting model, and uncertainty analysis described in other sections of this report. The forecasting tool is configured to generate a deterministic (or set) forecast based on choices the user makes about key inputs. The forecasting tool has base data that yields a "reference forecast" for water demand for each of the water use categories (municipal, domestic well, industrial, and irrigated agriculture). The user can either retain the inputs used in the reference forecast, or can modify inputs to construct alternative scenarios. The outputs of the forecasting tool are deterministic – that is, the calculations result in just a single output value for water demand in any given year. (This contrasts with the uncertainty analysis described previously in this report, which generates a range of demand values in any given year. Figure 4 shows the components of the forecasting tool.

Forecasting Tool Capabilities and Functions

The modeling team anticipates the following uses for the forecasting tool:

- **Model Validation.** The forecasting tool contains processed data that a user can review for the different water use categories and different regions within the state. The modeling team encourages OWRD and stakeholders to compare these data, both internally within the model itself and externally with other data sources. This can help to both assess model validity and understand model limitations.

- **Alternative Scenarios.** The model is structured to readily enable a user to modify input values used in the water use forecast. These values can be adjusted for any of the four categories of water use. Table 2 lists input data that can be adjusted. With these parameters, the model offers flexibility for users to construct a wide range of scenarios for population growth, economic activity, water use efficiency, and climate effects throughout the 40-year planning period.

- **Seasonal Analysis.** The forecasting tool incorporates monthly variation in demands, as well as annual totals. The monthly breakdown can support analysis and adjustment of seasonal needs within each of the water use categories.

The forecasting tool is designed for application at the statewide level, or by county or administrative basin. As noted previously, it is not designed for localized planning, such as a single city, water district, or irrigation district.

Table 2. Parameters that can be Adjusted for Scenarios

Municipal Systems and Domestic Wells [1]	Self-Supplied Industry [1]	Irrigated Agriculture [1, 2]
• Population in the initial year. • Percent change over time (growth rate) • Indoor per capita water use by month. • Outdoor per capita water use by month.	• Total use in the initial year, by month. • Percent change over time.	• Irrigated acreage in the initial year. • Annual change in acreage, by crop. • Irrigation efficiency. • Conveyance efficiency. • Allocation of demands from county to administrative basin. (i.e., spatial distribution of irrigated acreage)

[1] Variables can generally be adjusted either by county or by administrative basin. Variables can generally be adjusted in five-year increments, allowing the rate of change to be adjusted over the 40-year planning period.
[2] Agricultural variables can be adjusted by crop (14 crop groups).

3.3 Model Limitations

As with any model used to describe or predict complex systems, the State/Regional Water Demand Model forecasting tool has limitations. The Department and outside users should be aware of these limitations in applying results or using the forecasting tool:

- Results from the demand forecasting tool should not be used for detailed planning at the local level. This forecast is at the statewide, county, or administrative basin scale and is not prepared for a small area such as a single city or irrigation district.
- Because of data limitations the results are best viewed as estimates, particularly in the "first generation" output described in this report.
- The forecasting tool is not used to forecast hydropower demands. Hydropower demands were defined using a review of existing hydropower facilities with storage reservoirs as a baseline.
- Total instream (ecological) demands were forecasted using existing instream water rights and scenic waterway flows as a base and projecting a similar level of instream need to areas where none is currently defined using a derived ratio to natural stream flow. Peak flow needs are beyond the scope of this project, and will be addressed as part of planned future study on basin yield.
- For purposes of this initial assessment, water needs are estimated as a total quantity, without regard to supply systems or supply constraints.
- Due to software requirements, the uncertainty capabilities were applied initially only to model runs prepared by the HDR modeling team; however, this capability can be set up for OWRD and other users later, if desired.

The remainder of this Section describes the methodology and calculations used in each of the four out-of-stream water use categories listed above. Section 6 describes ways the forecasting model and input data could be improved during subsequent phases of OWSCI.

Figure 3. Relationship Among Input Data, Forecasting Tool and Uncertainty Analysis

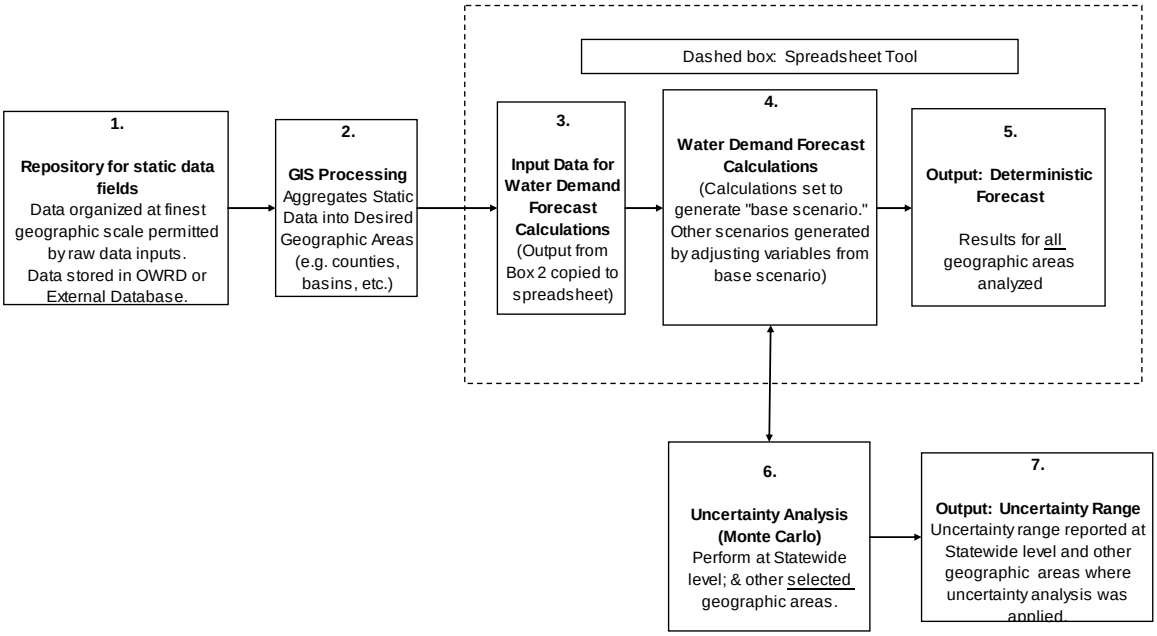
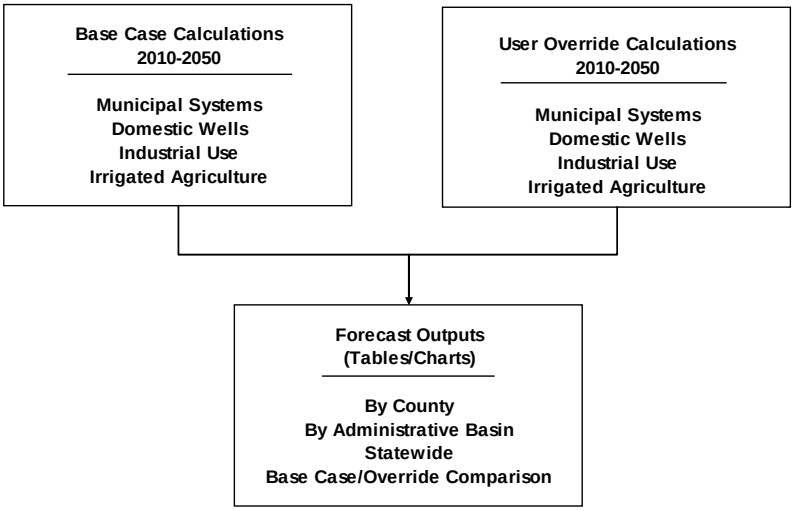


Figure 4. Components of Forecasting Tool



3.4 Municipal Systems and Domestic Wells

3.4.1 Definitions

For purposes of this analysis, the municipal systems category was defined to include any water system used to provide water to a group of nonagricultural customers. These include urban water systems that distribute water to homes, businesses, schools, and parks. In some areas industrial water users also receive water from a municipal system. Municipal systems may be private water systems operated by a homeowners association, larger systems managed by private water companies, or public systems operated by a city, town, or water district.

Some communities in Oregon receive drinking water from a municipal system and water for landscape irrigation separately from an irrigation district or irrigation company. The methodology used in this analysis includes any water used for homes and businesses (including landscape irrigation) in the municipal category, even if the water is supplied from an irrigation district or irrigation company.

The domestic well category is separate and covers single-family homes that have their own wells. These homes commonly are found in rural areas, but can also be present in urban neighborhoods.

3.4.2 Methodology

The demand forecasting approach for both the municipal and domestic well sectors are the same. They employ a simple per-capita forecasting approach. There were five main steps to the methodology:

1. **Assign characteristics to each Census block group.** To carry out other steps below, it was necessary to assign certain characteristics to each of the Census block groups. Characteristics assigned by the modeling team include the associated county, associated city if applicable, water administrative basin, water use class, climate zone, and portion served by public water systems compared to domestic wells. Water use classes were defined in order to account for differences in per capita uses between different types of communities and are described in Table 3.
2. **Develop population numbers.** The starting point was population by "block group" from the 2000 U.S. Census. There are 2,490 block groups in the State of Oregon. These data were then adjusted upward to reflect growth through year 2007 based on growth rates from Portland State University's *2007 Oregon Population Report*. The 2007 data were then projected to future years through 2050 based on growth rates from the Oregon State Office of Economic Analysis (OEA). Finally, the population numbers at the block group level were summarized by county and administrative basin.

   Note that there is a slight discrepancy between the total population by block group and by basin. These numbers match 100% in 2007, but they begin to vary in 2010 and the variance increases over time. By 2050, the total population by basin is 99.8% of the total population by block group. The discrepancy occurs more in the domestic wells sector than in the municipal systems sector. For example, by 2050, in the domestic sector, the

total population by basin is 96.4% of the total population by block group, while in the municipal sector, the total population by basin is 100.2% of the total population by block group. The discrepancy is at least in part associated with the weighted average growth rate needed since the boundaries for block groups and basins do not align perfectly. Despite the discrepancy, the numbers were deemed acceptable for "policy-level" analysis.

3. **Subdivide population into Municipal System and Domestic Well.** The modeling team allocated the 2000 population figures within each block group between those estimated to be served by public water systems and those served by domestic wells. The basis for this was the same water use classes described in Step 2 above. Table 3 illustrates the assumptions used to subdivide population between municipal systems and domestic wells.
4. **Develop representative per capita demands.** Within each climate zone across the state, a representative per capita demand was estimated for each of the four water use classes. The five climate zones are: 1) Oregon Coast, 2) Willamette Valley, 3) Southwestern Valleys, 4) Northern Cascades, and 5) Central. The per capita demands were developed using data from up to three public water systems for each water use class/climate zone combination. Representative water systems used to estimate the per capita demands were based largely on data availability (e.g., from surveys or plans). They are listed in Table 3.
5. **Calculate the baseline forecast.** The baseline forecast is calculated by multiplying population by per capita demand. The population grows over time as indicated in Step 2 above. The per capita demand from Step 4 was held constant over time, in the baseline scenario.

Table 3. Summary of Water Use Classes for the Municipal Systems and Domestic Well Sector

Water Use Class	Representative Water Users	Per Capita Demand Calculation	Municipal System vs. Domestic Well
Full Service – Industrial Skewed (FS-IS)	Represents communities with single family, multifamily, and non-residential water use. These communities are also assumed to have a commercial/industrial component with high water use that may skew per capita water use on the high side.	(production)/(population served)	Assume 100% served by public water system.
Full Service – Regular (FS-R)	Represents communities with single family, multifamily, and non-residential water use. These communities are assumed not to have a commercial/industrial component with high water use that would skew the per capita calculation.	(production)/(population served)	Assume 95% served by public water system and 5% by domestic well.
Primarily Residential (PR)	Represents communities that are primarily single-family residential in nature, with very little multifamily or non-residential water use.	(single family sales)/ (population served)	Assume 75% served by public water system and 25% by domestic well.
Domestic Well (DW)	Private, domestic wells serving individual homes.	Use the same per capita demand calculated for the PR Class above.	Assume 100% served by domestic well

Table 4. Public Water Systems (PWS) Used for Developing Per Capita Demands

Climate Zone	Water Use Class: Full Service - Industrial Skewed (FS-IS)					Water Use Class: Full Service - Regular (FS-R)					Water Use Class: Primarily Residential (PR)					Water Use Class: Domestic Well (DW)	
	PWS #1	PWS #2	PWS #3	Average Per Capita Demand (gal/day)	% of Total Population	PWS #1	PWS #2	PWS #3	Average Per Capita Demand (gal/day)	% of Total Population	PWS #1	PWS #2	PWS #3	Average Per Capita Demand (gal/day)	% of Total Population	Average Per Capita Demand (gal/day)	% of Total Population
1. Oregon Coast	*Portland*	*Salem*	*Hillsboro*	136	2	Brookings	Bandon		147	2	*Monroe*	*Town of Adair*	*Cascade View*	89	1	89	1
2. Willamette Valley	Portland	Salem	Hillsboro	136	48	Sunrise Water Authority	Oak Lodge Water District	Woodburn	113	11	Monroe	Town of Adair	Cascade View	89	7	89	3
3. South-western Valleys	Medford			284	4	Myrtle Creek			130	2	Alsea County Service			88	2	88	2
4. Northern Cascades	N/A	N/A	N/A	N/A	0	*Sunrise Water Authority*	*Oak Lodge Water District*	*Woodburn*	113	0.1	*Monroe*	*Town of Adair*	*Cascade View*	89	0.1	89	0.2
5. Central	Pendle-ton			202	3	Baker City			215	6	Echo			303	3	303	2

Notes:

- *Green shading and bold indicates the systems came from the same climate zone being estimated. Yellow shading and italics indicates the systems are located in a different climate zone and were used due to lack of specific data from communities within the target climate zone.*
- *Climate Zones are based on Oregon Climate Service classifications (some zones were consolidated for this analysis). See Appendix A.*
- *As the values show, the Domestic Well category uses the same water use values as the primarily residential category.*

This page intentionally left blank.

Because the per capita demands are critical to the demand forecast, it is important to have a clear understanding of the methodology and results. As shown in Table 4, there is variability regarding the success of applying the methodology and the resulting numbers.

The intent was to use three utilities from each climate zone/water use class combination to calculate the representative per capita demand. As shown in Table 4, it was not always possible to fully implement this method due to lack of data. If data from three utilities were not available, the average was developed either with a smaller number of utilities or from using utilities from another climate zone. Below is a summary of the robustness of the methodology for each climate zone.

- **Oregon Coast Climate Zone** – The methodology worked moderately well for the FS-R water use class since data were available from two utilities. However, it did not work well for the FS-IS and PR water use classes, since no data were available for them from the climate zone. This climate zone represents approximately six percent of the statewide population.

- **Willamette Valley Climate Zone** – The methodology was very robust for this climate zone since each water use class incorporated data from three representative utilities. This success provides significant reliability to the demand forecast since this climate zone represents approximately 70% of the statewide population.

- **Southwestern Valleys Climate Zone** – The methodology worked moderately well for this climate zone. A positive aspect is that there were data for each use class, however a negative aspect is that data were only available for one utility within each class. This climate zone represents approximately only ten percent of the statewide population.

- **Northern Cascades Climate Zone** – The methodology was not successful for this climate zone since no data was available for this climate zone and the per capita demands are based on utilities from another climate zone. This climate zone represents less than one percent of the statewide population.

- **Central Climate Zone** - The methodology worked moderately well for this climate zone. A positive aspect is that there were data for each use class, however a negative aspect is that data were only available for one utility within each class. This climate zone represents approximately 13 percent of the statewide population.

Table 4 also provides useful insight into the resulting per capita demands. The per capita demands range from 88 gallons per capita per day (gpcd) for the Southwestern Valleys climate zone and the Primarily Residential water use class to 303 gpcd for the Central climate zone and the Primarily Residential class. The per capita demands are mostly higher in Eastern Oregon compared to Western Oregon, as is expected due to drier conditions, higher temperatures, and therefore greater irrigation needs. Within each climate zone, the per capita demands are typically highest for the Full Service – Industrial Skewed water use class and lowest for the Primarily Residential and Domestic Well classes, which is what would be expected.

The model permits the annual population growth rates and per capita water use factors to change over time for alternative scenario building. For the first generation model, growth rates can be adjusted to reflect differing growth scenarios only at the county and basin level by external users.

3.4.3 Data Sources

This section describes sources of data acquired for the Municipal System and Domestic Well water use categories. Because OWRD may wish to update the State/Regional Water Demand Forecast from time to time, information is also provided regarding future updates to these data sources.

- **2000 U.S. Census:** Population in year 2000 by census block groups. This was the starting point for calculation of all the forecasted population values used in the model to project water use in the Municipal Systems and Domestic Wells categories. The Census defines 2,490 block groups in Oregon. The next Census is scheduled to be conducted in 2010, with new block group population data likely available in approximately 2012.

- **PSU Population Research Center's *2007 Oregon Population Report*:** "Table 4 Population Estimates for Oregon and Its Counties and Incorporated Cities." These data are not organized by Block Group as with the Census. Instead, Portland State University (PSU) has 2007 population estimates for each city and the collective unincorporated area for each county. The report also provides similar data for each year since 2000. These data were accessed at the following website: http://www.pdx.edu/media/p/r/PRC_2007_Population_Report2_rev.pdf.

- **Oregon State's Office of Economic Analysis:** Table: "Forecasts of Oregon's County Populations and Components of Change, 2000 – 2040." Three types of forecasts are provided: 1) total population, 2) population change, and 3) annual growth rates. These forecasts are available at the county level only and in five year intervals through 2040. Portland State University's Population Research Center developed the forecasts for the Office of Economic Analysis. The data was accessed at the following website: http://www.oregon.gov/DAS/OEA/demographic.shtml#Long_Term_County_Forecast.

- **Oregon State's Department of Human Services:** Database of drinking water systems. The DHS data were used to ground truth the assumptions utilized in estimating the percent of the population served by public water systems versus those served by a domestic well. For both public providers and domestic wells, the estimates used in the demand forecast model are within three percent of the population served according to the DHS database. A complete description of this process is described in **Appendix C**. The data were accessed at the following website: http://170.104.158.45/inventorylist.php3.

- **Project Survey:** Production, sales, and population data from the survey described in Section 2 were used to develop per capita demands.

Several additional sources were reviewed but were not used directly in the analysis due to data limitations. These include:

- **Water Management and Conservation Plans (WMCPs)** submitted by municipal water systems to OWRD under Oregon Administrative Rules 690-086. The modeling team received 40 WMCPs from OWRD. Per capita demand was reported in many of these plans, but the methodology for calculating these values was not reported in sufficient detail to check comparability from one system to another. Population data from these plans was also reviewed, but was not directly comparable with Census data without extensive data processing to compare service areas with Census Block boundaries. Instead of using WMCP's directly in the analysis, they provided information at a gross level to cross-check the validity of per capita demands calculated by the method described above.

- **OWRD water use reports:** ORS 537.099 requires federal and state agencies, cities, counties, schools, irrigation districts, and other special districts report water use on an annual basis. They are not, however, required to report the type of use, the amount of wholesale water or the population served. The water use reports do not contain the level of detailed required for the demand forecast analysis.

3.4.4 Limitations and Data Gaps

Users of the water use forecasts should be aware of the limitations and data gaps identified for the Municipal Systems and Domestic Well categories. During subsequent stages of OWSCI there may be opportunities to improve on the methodology and address some of these items.

- The methodology applied to these water use categories proposed to rely on three representative water systems in each combination of system class and climate zone to establish the per capita water usage for that combination. For some areas, however, three representative systems were not available with sound data. Out of 42 representative systems needed for this analysis, 17 were obtained (40 percent). The modeling team either substituted values from other climate zones, or used a single water system rather than three to fill these gaps (see Table 4). The forecast would be improved by acquiring additional data to fill these gaps. Additionally, the forecast would be further improved if the number of utilities included in the average were increased from three to include more utilities where possible.

- A more accurate forecast could be developed if actual water uses from more systems were used directly, instead of relying on averaging to produce representative per capita use values. This would require more extensive participation by water systems in all regions of the state. It would also require revisions of the model structure.

- The OEA forecast growth rates 2007-2040 are for each county as a whole. The growth rates were applied to all cities and the unincorporated area in each county. This may understate urban block groups and overstate rural block groups. This is not a problem for the County forecasts, but could be a concern for other geographic breakdowns, including Administrative Basins.

- The current model structure results in slight differences in the total statewide demand for Municipal Systems and Domestic Wells, depending on whether results are summed by County or by Administrative Basin. This discrepancy is approximately 0.2 percent. The modeling team believes the discrepancy is caused by the allocation of census block population data to Administrative Basins. This should be modified in the next generation of the forecasting tool.

- The population forecasting procedure relied on data from three separate sources. The base population in year 2000 came from the U.S. Census. Growth rates from 2000 to 2007 came from PSU. Growth rates for 2007 to 2050 came from OEA. Each of these sources use different (though related) geographic breakdowns, which required the modeling team to apply certain assumptions in order to carry out the forecast. It would be preferable to start with Census data and then apply growth rates from a single source to the preferred geographic breakdown throughout all subsequent years; however, this would likely require more extensive coordination with population forecasting agencies and may require additional funding.

- The forecasting method relies on professional judgment to determine which water use class is applied to each Census block group. That determination is essentially based on the presence and size of a city or town in relationship to the block group, as described in **Appendix C**. The presence and size of a city or town is used as a to estimate the intensity of the water use in the block group. Having more empirical data on the water use intensity would make the demand forecast more robust.

The modeling team was aware of these issues during the forecasting process. The limitations were discussed and incorporated in the analysis of variables conducted as part of the uncertainty analysis (see Section 4.1). The modeling team believes that the range of forecasts and associated probabilities yielded by the uncertainty analysis largely compensates for these limitations.

3.5 Industrial

3.5.1 Definition

The Industrial water use category represents self-supplied industrial and commercial facilities that have their own water rights separate from municipal systems. These include a variety of uses, from small facilities to major industrial plants. It is important to recognize that much of the State's industry is not contained in this category. Most commercial and industrial facilities receive water from municipal systems, and those facilities are covered under the Municipal Systems category of this analysis. The Industrial category includes only those facilities with their own, separate supplies. It was necessary to treat these facilities separately because the data and methodology needed to forecast this category is different from those used in the Municipal Systems category.

3.5.2 Methodology

The methodology used to forecast this category consisted of the following steps:

1.) Identify industrial users based on OWRD water rights records. This included seven categories under the State's water use classification system: Manufacturing (IM), Commercial Uses (CM), Shop (SH), Sawmill (SM), Log Deck Sprinkling (LD), Laboratory (LA), and Geothermal (GT). The initial query of the OWRD water rights GIS database returned approximately 2500 records. After cleaning the raw data (removing duplicate records, outliers, etc.) there were approximately 1830 records. The analysis did not estimate water demand for each separate category; rather these were all classified under a generic "industrial" category.

2.) Determine nominal water rights based on OWRD records. The instantaneous water right was used. This represents the maximum quantity a water rights holder is permitted to divert or pump on an instantaneous basis. It is measured in gallons per minute or cubic feet per second. For most users, this value is far higher than the average quantity diverted or pumped year-round.

3.) Apply standard assumptions to all users identified to convert nominal water rights into estimated use. The standard assumptions were:

- On average, facility operations use one-half the instantaneous water right.
- On average, facilities operate at this level for two shifts (16 hours) per day, seven days a week, every week of the year.

This methodology is viewed as a temporary and provisional approach. For further information, see Limitations and Data Gaps, below. The modeling team recognizes that actual water uses at each facility may be considerably different than the values yielded by this approach.

3.5.3 Data Sources

A single data source was used for this category: OWRD's water rights geodatabase. These data are accessed through the OWRD website, and available in shapefile format by each Administrative Basin. The water rights data is separated into two categories: point of diversion (POD) and place of use (POU), and both have associated data tables related to them. The industrial demand analysis was completed using the POD data.

The geodatabase was queried for the above industrial water use categories, and the results were exported into Microsoft Excel for further processing. The exported data was vetted to remove duplicate records and outliers. Industrial storage rights are not included in the analysis as these rights do not have an instantaneous volume that can be applied to the methodology. Once the data were cleaned, the industrial demand was calculated using the previously described methodology and summarized at both the county and administrative basin scale.

3.5.4 Limitations and Data Gaps

The methodology used for the Industrial water use category is viewed as a temporary and provisional approach. The modeling team recognizes that actual water uses at each facility may

be considerably different than the values yielded by this methodology. Water use in this category can fluctuate substantially from month-to-month and from year-to-year. Some water rights may be inactive. Other users may exceed permitted levels of water use; however, more accurate estimates would require one-on-one contact with water users to make a determination. Because of the number and diversity of users in this category and the reluctance of some private-sector users to provide operational data, a more in-depth data collection effort was considered infeasible for the initial forecasting effort. The provisional methodology described here enables this category of water use to be represented at least to an order-of-magnitude within the forecast, in the absence of more detailed data.

The Industrial water use category is likely among the smaller water uses in many parts of the state (recall this category does not include industrial uses supplied by Municipal Systems). Because of this, the data limitations described here are not considered highly problematic for the statewide forecast or for areas where there are large agricultural or municipal demands. However there are areas where self-supplied industry may be the dominant water use, especially areas that have major, self-supplied industrial facilities and where there are no large cities or extensive irrigated agriculture. In those areas it is especially important to consider improving on these estimates.

The modeling team was aware of data gaps and limitations for the Industrial category during the forecasting process. The limitations were discussed and incorporated in the analysis of variables conducted as part of the uncertainty analysis (see Section 4.2). The modeling team believes that the range of forecasts and associated probabilities yielded by the uncertainty analysis largely compensates for these limitations.

3.6 Irrigated Agriculture

3.6.1 Definition

The irrigated agriculture category includes water used to irrigate farm land. Farms may have their own independent surface or groundwater supplies or may receive water as part of an irrigation district or irrigation company. Stock watering is also included as part of the agricultural demand.

3.6.2 Methodology

The following steps were used to calculate the baseline water demand for irrigation, at the county level:

1. Estimate acreage used for growing each irrigated crop group, by county throughout the state.
2. Multiply acres of each crop group by the county-specific, average irrigation requirement for that crop group. This provides estimated consumptive use for each crop group in each county.
3. Divide consumptive use by estimated irrigation efficiency and estimated conveyance efficiency (these are fractional values, so division <u>increases</u> the quantity of water). This provides an estimate of total water diverted or pumped, by crop group for each county.

Expressed as an equation, this procedure is:

- $D_c = [(A \times I) \div E_i] \div E_c$

Where:

- D_c represents total demand for the crop group
- A = irrigated acreage in that crop group
- I = irrigation requirement for that crop group, expressed in inches or acre-feet
- E_i = irrigation efficiency for that crop group (the fraction of water applied to a field that is actually consumed by the crop. This fraction depends in part on the irrigation technology used.)
- E_c = conveyance efficiency for that crop group (the fraction of water diverted or pumped that actually reaches the field. This fraction depends on the type and condition of conveyance facilities and the distance from the water source to the field).

The total agricultural water use in each county is estimated by summing water use for all of the crop groups grown in that county. These results can also be allocated by Water Administrative Basins.

The model also provides for allocation of total water use to months in the irrigation season for each crop group in each county using a monthly distribution pattern developed from crop-specific regional data. Climate zones defined by the Oregon Climate Service (OCS 2008) were used to incorporate climatic variation in monthly irrigation patterns. Counties were assigned to climate zones, and selected, major crop groups within each climate zone were assigned a monthly irrigation pattern using the estimated monthly irrigation requirements provided in the Oregon Crop Water Use and Irrigation Requirements Report (Cuenca et al, 1992). Climate zones and associated counties are shown in **Appendix A**.

To apply this methodology, the wide variety of crops grown in Oregon was consolidated into 14 "crop groups," or categories of crops that have similar irrigation requirements. An additional category was generated for stock watering. Similarly, eight climate zones were used in the analysis of climatic variation in monthly irrigation patterns, although some sources (e.g., Cuenca et al. 1992) include a greater number of climate zones. Additional specificity with regard to crop irrigation requirements or climate could be incorporated into the analysis with further research.

A generalized estimate of a contributing factor was included as a "place holder" in the demand forecast model, with the intent that these factors could be updated with more accurate data in the future. For example, sufficient data was not available to account for the potential loss of water from conveyance systems (i.e., evaporation or seepage and waste from irrigation canals). A conveyance efficiency of 80 percent was assumed for all crops and counties in the forecasting tool (the uncertainty analysis then defined 80% as the median of the distribution of values). This value represents groundwater and surface water systems together, so it is higher than a typical value for surface water systems alone, which because of evaporation has lower efficiencies. This assumption could be refined with further research.

The reference forecast in the forecasting tool is the modeling team's "best estimate" of future agricultural demands based on professional judgment and analysis of information collected for this project. The change in water demand for irrigated agriculture under the reference forecast is driven by the change in total irrigated agriculture (i.e., the rate of increase or decrease). Data shows an overall increasing trend in irrigated acreage in the state since the early 1960's, with the past 10 years showing a slight declining trend. However, the fluctuations in irrigated acreage are dependent on water availability limits (i.e., hydrologic limits), climatic conditions (e.g., drought), economic conditions (e.g., commodity prices), regulatory constraints (e.g., water rights and Endangered Species Act), and land use policies (e.g., expansion of development and impacts on land value) among other factors.

Based on the data available, input received from stakeholders, and the judgment of the modeling team, the *reference forecast* generally assumes an overall *increase* in irrigated acreage statewide over the planning period. The rate of change in irrigated acreage is applied to every crop group uniformly, which assumes that counties will tend to continue to grow their current primary crop groups. While there are market forces that could cause a statewide shift to certain crop types, it was beyond the scope of this project to do such an economic analysis. **Appendix D** includes the basis and assumptions entered into the forecasting tool for the change in irrigated acreage for each county over the course of the planning period.

There are several factors that may drive water use up or down in the agricultural sector. The forecasting scenarios and uncertainty analysis are intended to capture the range of outcomes that can reasonably be expected through planning period. The scenario analysis was used to explore alternative futures based on assumptions about increased water use efficiency (conservation scenario) and potential effects of climate change (climate change scenario). OWRD and stakeholders can use the forecasting tool to explore other scenarios for agricultural water needs. For example, the ability to change crop mixes within the spreadsheet tool (say, as a result of changes in relative crop prices) offer an indirect way of understanding how relative crop prices may influence water consumption. Also, the use of general trends in water consumption over time to forecast future consumption patterns captures some of the underlying economic forces at work in determining the market for irrigation water. Finally, irrigated acreage can be used to account for how land-use changes (i.e., the conversion of agricultural land to urban land, or vice-versa) affect agricultural water use.

3.6.3 Data Sources for Irrigated Agriculture

The data sources used in this analysis, and the assumptions made with regard to the use of this data, are described below.

- **U.S. Geological Survey (USGS) 2005 Water Use Compilation (Fisher 2008).** The U.S. Geological Survey (USGS) conducts a water use compilation for nine water use sectors every five years. The compilation for the agricultural sector includes estimates of the following factors for a variety of crops by county:
    - Irrigated acres
    - Crop water requirements

- Consumptive use
- Irrigation efficiency
- Total water use

The 2005 compilation included data for 39 different crops. The USGS compilation also included estimated total water use by county for stock watering. The results of the 2005 compilation are expected to be published in late 2008. Provisional data was provided for use in this project by Bruce Fisher of the Oregon Water Science Center.

The 2005 USGS compilation is based on crop acreage data from the Oregon Agricultural Statistics Service and consumptive use estimates from Oregon State University's *Oregon Crop Water Use and Irrigation Requirements* (Cuenca et al. 1992). The USGS compilation augmented these sources with qualitative information, such as interviews with cooperative extension agents, irrigation district managers, and industry association representatives; climatic data and precipitation reports; and a variety of references that provided estimates of irrigation requirements. This information was used to calculate estimates of consumptive and total water use by crop in each county. Although the data provided by USGS was provisional, the modeling team determined that the use of the USGS compilation provided the most robust data set available for use in this analysis.

- **Oregon Crop Water Use and Irrigation Requirements (Cuenca, et al. 1992).** This report provides estimated monthly and seasonal irrigation requirements of major crops for 18 climate zones in Oregon. The report also provides requirements and monthly distribution of irrigation requirements for a range of return periods, from average, up to one year in 20. The crop irrigation requirements reported in USGS compilation are based on the average net irrigation requirements reported in the Cuenca report.

  The Cuenca report was used to develop average monthly irrigation patterns for use in the baseline demand estimate. Where possible, crop-specific monthly net irrigation requirements from the Cuenca report were used; a general pattern was developed as a "place holder" for crops not included in the Cuenca report.

- **National Land Cover Database (NLCD) Land Cover Layer (USGS 2001) .** The National Land Cover Database (NLCD) was used to allocate irrigated acres from county-level data to develop estimates of irrigated acres and water demand for each Water Administrative Basin. The NLCD was used to geographically associate each county's irrigated acreage with a Water Administrative Basin, then reallocate the crop groups and associated demands to each Basin. The NLCD uses spatial imaging to categorize types of land cover such as pasture, cultivated crops, forest, and developed land. A Geographic Information System (GIS) was used to identify areas in each county that were categorized as pasture or cultivated crops in the NLCD, and then assign these areas to Water Administrative Basins. The crop group data for each county was then used to calculate

percentages of each crop group found in each Water Administrative basin, based on the percentage of each county's acreage associated with each crop group[1].

- **2002 U.S. Census of Agriculture (USDA 2004).** Census of Agriculture data used in this project was obtained from the Oregon State and County Data, Volume 1, Geographic Area Series, Part 37; County Data Tables 10 (Irrigation) and 23 (Selected Crops Harvested). These tables provide data by county for irrigated acres and harvested and irrigated acres of selected crops. The Census was used primarily as a tool to verify that agricultural acreage estimates contained in the USGS data set were comparable to the Census.

- **Project Survey**. A survey of water users was conducted to inform the demand forecast and conservation inventory. There were a limited number of responses from the agricultural sector, and the responses received were in a format that was not easily adapted to fit the statewide demand forecast model. For example, data were provided by irrigation districts for their service area; there was no way to calibrate these data with the county- and basin-level estimates used in the demand forecast. As such, the data collected in the project survey were not directly usable in the demand forecast model. However, the survey responses were useful in developing the conservation inventory database for OWRD.

3.6.4 Limitations and Data Gaps

Users of the water use forecasts should be aware of the limitations and data gaps identified for the Irrigated Agriculture and Stock Water sectors. During subsequent stages of OWSCI there may be opportunities to improve on the methodology and address some of these items.

- Agricultural water use data is typically incompletely recorded and of lower accuracy, compared to municipal water use data. The state of Oregon requires irrigation districts and special districts to report water use and many new permits have required annual reports to be submitted to the state. In general, however, reporting is still considered incomplete.

- The USGS 2005 Water Use Compilation, though considered by the modeling team to be the most robust data set available for use in the model, was at times difficult to work with due to some discrepancies in formulae and other data anomalies. It may be possible in the future to coordinate with the USGS to improve the usability of the data collected as part of the next Water Use Compilation.

- The methodology applied to the Irrigated Agriculture and Stock Water sectors uses representative data for several factors or "place holders" where data was incomplete or not readily available (i.e., irrigation efficiency, conveyance efficiency) to establish per

[1] For example, if the NLCD data defines 100 acres of cultivated land in Basin A and County B, and 200 acres of cultivated land in Basin C and County B, and the USGS says 100 acres of wheat in County B, the model used 100/300 times 100 acres of wheat in Basin A, and 200/300 times 100 acres of wheat in Basin B.

acre water usage for agricultural irrigation. The forecast would be improved by acquiring additional and more refined data to fill these gaps.

- The estimation of future water demand for agricultural irrigation is inherently complex, and is dependant on a variety of social, political, and economic factors that were not used directly in this demand forecast model.

- The water "demand" estimates do not reflect future assumptions regarding the price of agricultural products or water and thus should not be viewed as economic demand relationships. To perform a detailed demand analysis (in economic terms) is beyond the scope of this project.

- A more accurate forecast could be developed if actual water use data were collected from irrigators directly, rather than relying on estimates of water used based on crop water needs to produce representative per acre use values. This would require more extensive participation by irrigators in all regions of the state, as well as analysis of the data collected to aggregate to the appropriate geography (i.e., irrigation district to county) to fit into the model structure.

The modeling team was aware of data gaps and limitations during the forecasting process. The limitations were discussed and incorporated in the analysis of variables conducted as part of the uncertainty analysis (see Section 4.3). The modeling team believes that the range of forecasts and associated probabilities yielded by the uncertainty analysis largely compensates for these limitations.

This page intentionally left blank.

4.0 Statewide Demand Forecast Results

The results of the statewide demand forecast are discussed in terms of the reference forecast and the results of the scenario analysis. The *reference forecast* in the forecasting tool represents the "best estimate" forecast by the modeling team based on the available data, methodology and professional judgment used in the project. It is considered one potential future outcome.

With the uncertainty surrounding each of the input variables, the scenario analysis characterizes the uncertainty around the data used to develop the demand forecast, as well as characterizing the impacts of two key issues impacting water demands: climate change and water conservation. The "base case scenario" is used to describe the overall uncertainty around the data itself and the resulting uncertainty around the demand forecast. The climate change scenario considers how changes in water use factors (per capita water use and irrigation requirement) from climate change could affect water demand. Finally, the conservation scenario considers broadly how achieving a range of water savings could affect water demand.

In the subsections below, the reference forecast is discussed first, followed by the scenario analysis for each of the water use categories (municipal/domestic, self-supplied industrial, and agricultural). The reference forecast and scenario analysis results should not be directly compared, because as described above, their purpose in the study is different.

4.1 Reference Forecast Results

4.1.1 Total Statewide and County-Basin Results

The statewide water demands for the reference forecast are shown in Table 5 and show the *reference forecast* results for the major water use categories. The "reference forecast" in the forecast tool shows an overall increase in annual water demand of ~1.2 million acre-feet (~1,100 million gallons per day). The majority of the annual demand increase is due to irrigated agriculture (~900,000 acre-feet) followed by municipal (300,000 ac-ft), domestic well (50,000 ac-ft). The change statewide in the domestic well demand is forecasted to be significantly smaller than those in the municipal and irrigated agriculture categories. The agricultural sector generally accounts for over 85% of statewide demand, thus the overall change in statewide water demand will be driven significantly by the amount of irrigated acreage and agricultural water use practices. Of course, one of the largest uncertainties is associated with self-supplied industrial demand. Recall, the self-supplied industrial demand is assumed to remain constant over the planning period on a provisional basis. In general, the type of industry can have the single largest impact within a county or basin on total demand; alternatively, lack of available water to meet the industry's demand can be the single largest constraint to development or growth.

The reference forecast is based on population growth rates and changes in irrigated acreage for each county derived from available information. Table 5 summarizes the change in demands for each county from 2010 to 2050, while Table 8 summarizes the change in demand for each administrative basin over the same period. The results are presented in terms of percent change from 2010 to 2050, as well as total change in demand. Table 9 presents the demand reference forecast by county for each water use category for 2010 and 2050. Figure 7 shows the change in total demand by county from 2010 to 2050.

The proportion of the change in total statewide demands discussed above varies across the state. For many areas the largest change in demands over the planning period are associated with the forecasted change in irrigated acreage. Counties forecasted to have greater than 20% increase in total demand resulting primarily from increased irrigated agriculture include Baker, Gilliam, Grant, Harney, Morrow, Sherman, and Umatilla counties. Counties with more moderate demand increase (10-15%) resulting from agricultural irrigation include Malheur, Union, and Wallowa counties. Although the percent increase in water demand is not as high as other counties, Malheur County is forecasted to have one of the largest net volumetric increases in demand over the planning period as a result of increased irrigation.

Counties with greater than 20% increase in total demand driven primarily by municipal needs (population growth) include Clackamas, Deschutes, Polk, Washington, and Yamhill counties. Other counties with more moderate demand increase (10-15%) resulting from municipal needs include Douglas, Jackson, Josephine, Lane, Lincoln, and Multnomah counties. Washington, Clackamas, and Deschutes counties are forecasted to have the largest net volumetric increase in demand over the planning period as a result of increased population (municipal demand).

The water demands in some counties are forecasted to remain relatively stable or even decrease slightly over the planning period, because population and irrigated acreage are not expected to increase significantly; or alternatively the net change between the two sectors could cause only minor change in overall water demand. These counties include Coos, Klamath, and Wheeler counties. It is debatable whether Klamath County's demands will increase significantly. While population is expected to grow at a moderate pace, the change in irrigated acreage is highly uncertain. There are significant policy issues that can drive irrigation to increase or decrease, depending on how the reservoirs in the basin are operated. For the purposes of this study, it was assumed that irrigated acreage decreases slightly in the region over the planning period.

Table 8 presents the change in demand from 2010 to 2050 in terms of the administrative basins. The basins with the largest increase in irrigated acreage have the largest percent increase and net increase in volumetric demand over the planning period. These administrative basins include Deschutes, John Day, Klamath, Powder, North Coast, Umatilla, and Willamette basins.

4.1.2 Reference Forecast Results - Municipal and Domestic

Figure 7 and Figure 8 show, respectively, the relative geographic distribution of municipal and domestic well demand statewide by county. As expected, the largest municipal demands are in counties with metropolitan statistical areas (MSA). These include Multnomah, Washington, Clackamas, Lane, Jackson, Marion, and Deschutes counties, which comprise almost 69% of the municipal demand. These counties (because of the MSAs) are assumed to continue having the largest population growth rates through the planning period. In 2050, these counties project 70% of the total municipal demand.

The largest domestic well demands are in Deschutes, Clackamas, Klamath, and Lane counties followed by Jackson, Washington, and Josephine counties. These counties include areas with relatively large municipal centers to support or drive rural development. These counties comprise 54% of the domestic well demand in 2010 and 56% in 2050.

Counties forecasted to have the greatest increase in municipal water demand through the planning period include Washington, Clackamas, Deschutes, Multnomah, Jackson, Marion, and Lane counties – comprising over 224,000 acre feet (72%) of the municipal demand increase through the planning period. For the domestic well demand, Clackamas, Deschutes, Washington, Jackson, Jefferson, and Lane counties total over 27,000 acre-feet (57%) of the domestic well demand increase in 2050.

The modeling team compared results against available reports containing municipal demand forecasts for key water systems in several counties (reports were available for municipal demand in Clackamas, Douglas, Jackson, Multnomah and Washington Counties). These comparisons provided reasonable assurances that the forecasting methodology yields results comparable to other methods that have been used by municipal water systems to forecast their demands.

4.1.3 Reference Forecast Results – Self-supplied Industrial

Figure 9 shows the relative distribution of self-supplied industrial demand statewide by county. The largest demands are in counties with metropolitan statistical areas (MSA) and larger population centers that provide work force and ports to support industries. These include Multnomah, Lane, Columbia, Clatsop, Clackamas, Marion, and Linn counties. These counties comprise 62% of the total self-supplied industrial demand. Other counties with relatively large self-supplied industrial demands include Coos, Umatilla, Deschutes, and Douglas counties, which comprise 15% of the total demand. While Washington County has significant industrial use, it is not shown to have large self-supplied industrial demand under this methodology. The industries in Washington County are likely served by municipal water providers.

4.1.4 Reference Forecast Results – Irrigated Agricultural

Figure 10 shows the relative distribution of agricultural demand statewide by county. The largest agricultural demands are in the southeastern counties of the state where large areas of agriculture exist. These include Malheur, Lake, Baker, Klamath, Harney, Umatilla, and Morrow counties. These counties comprise 66% of the total agricultural demand in 2010 and 67% of agricultural demand in 2050. Other counties with relatively large agricultural demands include Crook, Marion, Jackson, Grant, Deschutes, Wallowa, and Union counties, which comprise 21% of the total demand in 2010 and 2050.

Counties forecasted to have the greatest increase agricultural water demand through the planning period include Baker, Harney, Malheur, Umatilla, Morrow, and Lake counties – comprising over 750,000 acre feet (85%) of the agricultural demand increase through the planning period.

4.2 Scenario Results for Municipal Systems and Domestic Wells

4.2.1 Uncertainty Parameters

In the base case scenario analysis conducted for the Municipal Systems and Domestic Wells categories, the following input variables were allowed to vary over a prescribed range established by the modeling team:

- Population values in initial year (2007);

- Annual population growth rate;
- Per capita water use (total value, including indoor and outdoor uses).

Further information on the uncertainty analysis is contained in **Appendix F**. Figures in **Appendix F** also illustrate the range of values associated with the variables above.

4.2.2 Base Case Scenario

The range of water demands from the scenario analysis referred to in this section is listed in Table 9. The mean total statewide municipal sector demand is projected to increase from approximately 619,000 acre-feet annually in 2010 to over 1,000,000 acre-feet annually in 2050. The increase in municipal demand is driven by population growth under this scenario and assumes no defined change in per capita water use over the planning period. With respect to the domestic well sector, demand is projected to increase from approximately 92,000 acre-feet annually in 2010 to 154,000 acre-feet in 2050.

A fairly wide uncertainty range was applied to the annual growth rate and per capita water use in the base case analysis. As Figure F-1 (Appendix F) shows, the population range at 2050 is 4.5 to 7.5 million people, which is a wide range of uncertainty for population. Similarly, the per capita demand was allowed to vary by as high as 150% and as low as 75% of the mean.

The municipal sector demand ranges from 733,000 to 776,000 acre-feet in 2025, while the range increases from 985,000 to 1,058,000 acre-feet in 2050. In 2050, this is equivalent to a range of 65 million gallons per day (mgd). This range represents 80% probability that total statewide municipal demands will fall within this range based on assumptions used in the uncertainty analysis. Similarly, there is 80% probability that domestic well demand will range from 110,000 acre-feet to 115,000 acre-feet in 2025, and from 149,000 to 159,000 acre-feet in 2050 – a range of 9 mgd. Combined, the range of uncertainty in demand for the municipal and domestic well sectors for the entire state is 82,000 acre-feet (or ~75 mgd) at 80% probability.

4.2.3 Climate Change and Conservation Scenarios

In the climate change and conservation scenarios conducted for the municipal and domestic wells sectors, the range of values for following input variables were changed relative to the base case as defined by the modeling team:

- Climate change: increased outdoor per capita water use based on climate zone;
- Conservation: decreased total per capita water use.

Table 10 and Table 11 summarize the municipal demands associated with the climate change and conservation scenarios, respectively. Under the climate change scenario for municipal and domestic well sector, the demands increase overall through the planning period. By 2050 the mean municipal and domestic well demand was greater by 64,000 acre-feet relative to the statewide base case mean value. Under the conservation scenario, the mean municipal and domestic well demand was lower by 290,000 acre-feet statewide in 2050. The relatively large decrease under the conservation scenario is a result of the high percent of water use savings assumed by the modeling team (refer to Appendix F). Achievement of this level of conservation

would require substantial changes in how the public uses water, as well as significant investments in infrastructure and water management.

4.3 Scenario Results for Self-Supplied Industrial Water Use

4.3.1 Uncertainty Parameters

In the base case scenario analysis conducted for the Industrial category, the following input variable was allowed to vary over a prescribed range established by the modeling team:

- Total industrial water use, by county.

Further information on the uncertainty analysis is contained in **Appendix F**. The basic uncertainty assumptions are based around the demand estimate itself rather than independent variables.

4.3.2 Base Case Scenario

The range of water demands from the uncertainty analysis referred to in this section is listed in Table 9. The mean total statewide industrial sector demand is estimated to be approximately 476,000 acre-feet annually in 2010 to 490,000 acre-feet in 2050 using the base case assumptions. The range of industrial demands from the base case scenaro is lower than the reference forecast, because of the uncertainty range defined for the analysis. However, the mean industrial demand tends to increase over time because the range of uncertainty is greater over time as defined by the modeling team.

Based on the uncertainty assumptions, there is an 80% probability that the statewide self-supplied industrial demand will be between 460,000 and 494,000 acre-feet in 2025 and between 466,000 and 513,000 acre-feet in 2050. The uncertainty range increases through the planning period since the values around the input variables also increases.

4.3.3 Conservation Scenario

Only a conservation scenario was conducted for the self-supplied industrial sector. The following input variable was changed and allowed to vary over a prescribed range established by the modeling team:

- Conservation: decreased industrial water use (per methodology).

Table 11 summarizes the self-supplied industrial sector conservation scenario. Under the conservation scenario, the demands decreased overall through the planning period. By 2050 the mean self-supplied industrial demand was lower by 133,000 acre-feet relative to the statewide base case mean value. Achievement of these water savings would require substantial investments by private industry in water conservation.

4.4 Scenario Results for Irrigated Agriculture

4.4.1 Uncertainty Parameters

In the base case scenario analysis conducted for the Irrigated Agriculture category, the following input variables were allowed to vary over a prescribed range established by the modeling team:

- Crop acreage
- Crop water requirement
- Irrigation efficiency
- Conveyance efficiency.

Further information on the uncertainty analysis is contained in **Appendix F**. Figures in **Appendix F** also illustrate the range of values associated with the variables above.

4.4.2 Base Case Scenario

The range of water demands from the scenario analysis referred to in this section is listed in Table 9. Total statewide irrigated agricultural sector demand is estimated to be approximately 8,540,000 acre-feet annually in 2010 to 8,565,000 acre-feet in 2050 using the base case assumptions. Based on the uncertainty assumptions, there is an 80% probability that the statewide agricultural demand will be between 8,025,000 and 9,100,000 acre-feet in 2025, and between 7,890,000 and 9,260,000 acre-feet in 2050. The uncertainty range increases through the planning period since the values around the input variables also increase.

The base case scenario assumes that the median irrigated acreage remains the same through the planning period. This assumption is made because the purpose of the base case scenario is to understand the sensitivity of the water demand to the uncertainty around the independent variable(s) – in this case the uncertainty around the irrigated acreage, irrigation requirement, and irrigation/conveyance efficiencies). In any case, the mean irrigated agricultural demand increases slightly when the combined uncertainties in these variables are considered together.

The reference forecast in the forecast tool represents the modeling team's "best estimate" for the agricultural demands, whereas the base case scenario analysis represents a range of likely outcomes. By the end of planning period, the "reference forecast" yields a larger overall demand for the irrigated agricultural sector than the mean demand under the base case scenario analysis. However, the demands are still within the 80% probability range of demands predicted by the uncertainty analysis.

4.4.3 Climate Change and Conservation Scenarios

In the climate change and conservation scenarios conducted for the agricultural sector, the following input variables were changed and allowed to vary over a prescribed range established by the modeling team:

- Climate change: increased crop group irrigation requirement based on climate zone;

- Conservation: increased irrigation efficiency and increased conveyance efficiency.

Table 10 and Table 11 summarize the agricultural demands associated with the climate change and conservation scenarios. Under the climate change scenario agricultural sector, the demands are greater overall through the planning period. By 2050 the mean agricultural demand was greater by 220,000 acre-feet relative to the statewide base case mean value. This relatively small difference was driven in part on the assumed distribution for the irrigation requirements for the base case and climate change scenarios. Under the conservation scenario, the mean irrigated agricultural demand was lower by nearly 2,000,000 acre-feet statewide in 2050. This large difference between the base case and conservation scenario is driven by the assumed range of water savings defined by the modeling team. See **Appendix F** for details on the assumptions. Achievement of water savings of this magnitude would require substantial investments in agricultural irrigation technology and conveyance systems.

4.5 Summary of Scenario and Uncertainty Results

Two of the objectives for this project included: (i) improve OWRD's understanding of the overall magnitude of water uses for various water use categories in different regions across the state; and (ii) improve OWRD's understanding of the dynamic trends that affect these uses and how these trends may change in the future. This section summarizes the key points observed from the forecast results.

Figure 11 summarizes the statewide total demand under the base case, climate change and conservation scenarios developed for this project. The municipal and domestic water demand under the base case scenario shows an increase over time driven by population growth. The changes in agricultural and industrial demands are driven by the uncertainty range defined for the input variables (e.g. irrigated acreage). Based on the forecasting assumptions used, there is 80% probability that the total statewide demand in 2010 under the base case will range between 9.2 million and 10.3 million acre-feet. By 2050 this range is forecasted to be from 9.5 to 11 million acre-feet. If the "low" range of the total statewide demand forecast in 2010 is compared to the "high" range in 2050, the increase in total statewide demand is on the order of 1.8 million acre-feet.

Other notable findings from looking at Figure 11 include the relative changes in overall statewide demand under the climate change and conservation scenarios. Even with the assumed parameter constraints and uncertainties with input variables, it is clear that both climate change and water conservation can have drastic effects on water demands. Based on the assumed range of uncertainty under these scenarios, water conservation is shown to have a potentially significant affect on overall water demand. Furthermore, those impacts will vary across the state, as shown in Figure 6 through Figure 10 showing the county-by-county demands for each sector under the reference forecast. In the highly agricultural areas in the state agricultural conservation measures can yield significant reductions in overall statewide demand. In other areas, the impacts between municipal and agricultural conservation will have more balanced benefits. However, as noted previously, achievement of water savings of this magnitude would require substantial changes in public behavior, coupled with significant investments in consumer equipment, industrial plants, agricultural irrigation technology, and agricultural water conveyance infrastructure.

Climate change is also demonstrated to increase the overall demand statewide – although the impacts are smaller relative to the potential from conservation. Climate change was assessed primarily by adjusting the per capita water use factor and crop irrigation requirements. The overall impacts of climate change could also affect other factors such as irrigation season, irrigated acreage and population migration. Taking these factors into account could result in greater impacts on overall demand.

Section 4 Data Tables follow.

This page left intentionally blank.

Table 5. "Reference Forecast" from Forecasting Tool – Total Statewide Water Demand (Acre-Feet)

Years	Municipal Systems	Domestic Wells	Industrial	Agricultural	Total
2007	539,000	80,000	534,000	7,780,000	8,933,000
2010	559,000	83,000	534,000	7,881,000	9,057,000
2015	596,000	89,000	534,000	7,984,000	9,201,000
2020	635,000	95,000	534,000	8,089,000	9,353,000
2025	672,000	100,000	534,000	8,196,000	9,502,000
2030	709,000	106,000	534,000	8,306,000	9,655,000
2035	747,000	117,000	534,000	8,419,000	9,811,000
2040	787,000	118,000	534,000	8,534,000	9,973,000
2045	826,000	124,000	534,000	8,652,000	10,135,000
2050	869,000	131,000	534,000	8,772,000	10,305,000

Table 6. Change in Forecasted Demand by County – Reference Forecast (2010 to 2050)		
County	% Change in Demand (2010-2050)	Change in Demand (2010-2050) (acre-feet)
Baker	28%	218,000
Benton	5%	2,700
Clackamas	24%	47,000
Clatsop	2%	1,000
Columbia	9%	5,100
Coos	-2%	-1,100
Crook	6%	19,500
Curry	3%	600
Deschutes	19%	51,100
Douglas	12%	9,700
Gilliam	21%	3,700
Grant	21%	52,100
Harney	21%	155,000
Hood River	3%	2,200
Jackson	9%	27,200
Jefferson	4%	6,800
Josephine	15%	11,200
Klamath	-3%	-19,900
Lake	7%	54,200
Lane	13%	22,800
Lincoln	11%	2,040
Linn	7%	8,100
Malheur	11%	134,000
Marion	6%	22,500
Morrow	22%	93,600
Multnomah	13%	25,700
Polk	26%	17,600
Sherman	28%	9,900
Tillamook	8%	1,500
Umatilla	21%	121,000
Union	11%	21,700
Wallowa	14%	29,400
Wasco	8%	7,100
Washington	44%	69,100
Wheeler	-2%	-500

Table 7. Change in Forecasted Demand by Administrative Basin - Reference Forecast (2010 to 2050)		
Administrative Basin	% Change in Demand (2010-2050)	Change in Total Demand (2010-2050) (acre-feet)
Deschutes	24%	56,000
Goose & Summer Lakes	-1%	-300
Grande Ronde	12%	24,400
Hood	1%	3,900
John Day	20%	191,000
Klamath	8%	58,500
Malheur	3%	7,700
Malheur Lake	-2%	-1,400
Mid Coast	5%	4,400
North Coast	18%	114,000
Owyhee	1%	370
Powder	26%	226,000
Rogue	1%	12,600
Sandy	14%	5,100
South Coast	5%	26,500
Umatilla	15%	52,600
Umpqua	21%	9,700
Willamette	18%	461,000

This page intentionally left blank.

Table 8. County Demand by Water Use Category in 2010 and 2050– Reference Forecast (acre-feet)

	2010					2050					
County	Municipal	Domestic	Industrial	Agricultural	Total	Municipal	Domestic	Industrial	Agricultural	Total	Total Growth
Baker	3,700	908	3,900	777,000	786,000	3,990	978	3,900	994,000	1,000,000	218,000
Benton	11,600	1,180	6,020	33,000	51,800	14,000	1,420	6,020	33,000	54,500	2,620
Clackamas	43,300	8,160	35,500	106,000	192,000	79,300	14,900	35,500	109,000	239,000	46,500
Clatsop	4,500	979	39,300	2,100	46,900	4,860	1,060	39,300	2,690	47,900	1,030
Columbia	5,100	1,360	42,000	7,770	56,200	7,420	1,980	42,000	9,940	61,400	5,110
Coos	7,350	1,670	24,000	18,400	51,400	7,500	1,700	24,000	17,100	50,300	-1,100
Crook	6,090	2,090	5,860	326,000	340,000	11,900	4,080	5,860	338,000	360,000	19,500
Curry	1,990	962	1,400	15,200	19,500	2,200	1,060	1,400	15,400	20,100	566
Deschutes	37,500	8,450	19,000	210,000	275,000	67,000	15,100	19,000	225,000	326,000	51,100
Douglas	10,100	3,990	17,700	49,800	81,600	14,500	5,730	17,700	53,300	91,300	9,700
Gilliam	348	18	761	17,200	18,300	478	25	761	20,800	22,000	3,750
Grant	1,610	242	3,850	247,000	253,000	1,650	248	3,850	299,000	305,000	52,100
Harney	1,520	649	4,890	732,000	739,000	2,160	920	4,890	886,000	894,000	155,000
Hood River	4,650	1,930	9,510	67,300	83,400	7,880	3,270	9,510	64,900	85,600	2,170
Jackson	41,600	5,560	3,430	252,000	303,000	65,600	8,770	3,430	252,000	330,000	27,200
Jefferson	4,180	3,410	280	160,000	168,000	7,920	6,450	280	160,000	175,000	6,780
Josephine	14,300	4,500	4,890	51,500	75,200	22,100	6,960	4,890	52,400	86,400	11,200
Klamath	14,000	7,040	7,750	730,000	759,000	18,000	9,040	7,750	704,000	739,000	-20,000
Lake	1,570	791	1,260	763,000	766,000	1,630	819	1,260	817,000	821,000	54,200
Lane	43,000	6,110	78,700	43,700	172,000	63,700	9,040	78,700	43,000	194,000	22,800
Lincoln	5,390	1,010	11,300	1,450	19,100	7,020	1,320	11,300	1,550	21,100	2,040
Linn	12,700	1,920	30,400	66,600	112,000	18,700	2,830	30,400	67,800	120,000	8,100
Malheur	6,060	3,320	6,610	1,220,000	1,240,000	8,690	4,760	6,610	1,350,000	1,370,000	134,000
Marion	40,600	3,550	33,600	272,000	350,000	61,400	5,370	33,600	272,000	373,000	22,500
Morrow	3,250	513	4,880	426,000	435,000	6,450	1,020	4,880	516,000	528,000	93,600

Table 8. County Demand by Water Use Category in 2010 and 2050– Reference Forecast (acre-feet)

	2010					2050					
County	Municipal	Domestic	Industrial	Agricultural	Total	Municipal	Domestic	Industrial	Agricultural	Total	Total Growth
Multnomah	109,000	838	70,700	24,400	205,000	136,000	1,040	70,700	23,600	231,000	25,700
Polk	9,870	656	2,730	54,900	68,100	20,900	1,390	2,730	60,700	85,800	17,600
Sherman	404	135	359	35,200	36,100	469	156	359	45,100	46,000	9,930
Tillamook	1,870	1,420	5,970	9,030	18,300	2,350	1,790	5,970	9,670	19,800	1,480
Umatilla	16,100	2,160	21,200	528,000	567,000	25,100	3,350	21,200	639,000	689,000	121,000
Union	6,170	699	8,920	183,000	198,000	8,270	937	8,920	202,000	220,000	21,700
Wallowa	1,580	468	2,740	204,000	209,000	2,060	609	2,740	233,000	238,000	29,400
Wasco	5,570	517	12,500	73,700	92,400	7,280	675	12,500	79,000	99,500	7,090
Washington	69,800	4,810	7,600	73,600	156,000	137,000	9,430	7,600	71,000	225,000	69,100
Wheeler	395	132	0	32,900	33,400	426	142	0	32,300	32,900	-530
Yamhill	11,800	1,080	3,970	67,000	83,900	23,400	2,140	3,970	71,800	101,000	17,400

Table 9. Base Case Scenario – Statewide Water Demand (Acre Feet)											
Sector		2007	2010	2015	2020	2025	2030	2035	2040	2045	2050
Municipal Systems											
	Mean	597,000	620,000	662,000	707,000	754,000	802,000	851,000	902,000	959,000	1,021,000
	10% Percentile	580,000	603,000	643,000	687,000	733,000	779,000	825,000	873,000	926,000	985,000
	90% Percentile	613,000	636,000	680,000	726,000	776,000	825,000	878,000	931,000	992,000	1,058,000
Domestic Wells											
	Mean	89,000	92,000	99,000	105,000	113,000	120,000	127,000	135,000	144,000	154,000
	10% Percentile	87,000	90,000	96,000	103,000	110,000	117,000	124,000	131,000	140,000	149,000
	90% Percentile	91,000	94,000	101,000	108,000	115,000	123,000	131,000	139,000	148,000	159,000
Industrial											
	Mean	475,000	476,000	476,000	476,000	477,000	478,000	481,000	484,000	489,000	490,000
	10% Percentile	461,000	462,000	459,000	459,000	460,000	462,000	458,000	466,000	468,000	467,000
	90% Percentile	490,000	491,000	493,000	494,000	494,000	496,000	503,000	503,000	510,000	513,000
Agriculture											
	Mean	8,587,000	8,539,000	8,591,000	8,539,000	8,578,000	8,550,000	8,580,000	8,577,000	8,605,000	8,566,000
	10% Percentile	8,090,000	8,025,000	8,068,000	8,004,000	8,025,000	8,002,000	7,989,000	7,963,000	7,996,000	7,890,000
	90% Percentile	9,118,000	9,081,000	9,116,000	9,079,000	9,097,000	9,112,000	9,144,000	9,232,000	9,257,000	9,260,000
Total for All Sectors											
	Mean	9,748,000	9,728,000	9,827,000	9,828,000	9,922,000	9,950,000	10,039,000	10,098,000	10,196,000	10,231,000
	10% Percentile	9,218,000	9,179,000	9,267,000	9,253,000	9,327,000	9,359,000	9,396,000	9,433,000	9,530,000	9,490,000
	90% Percentile	10,313,000	10,303,000	10,390,000	10,407,000	10,482,000	10,556,000	10,655,000	10,805,000	10,908,000	10,990,000

Note: Refer to Appendix F for details on the assumptions used to define the range of values for the base case variables.

- *Mean – the average demand generated by the uncertainty analysis using Monte Carlo simulation*
- *10th percentile demand – represents the statistical "lower-end" of the range of possible demand based on the uncertainty analysis; the demand that is exceeded 90 percent of the time based on the results of the Monte Carlo simulation.*
- *90th percentile demand - represents the statistical "upper-end" of the range of possible demand based on the uncertainty analysis; the demand that is exceeded 10 percent of the time based on the results of the Monte Carlo simulation.*

Table 10. Climate Change Scenarios – Statewide Water Demand (Acre Feet)

Sector		2007	2010	2015	2020	2025	2030	2035	2040	2045	2050
Municipal Systems											
	Mean	578,000	601,000	643,000	689,000	738,000	786,000	836,000	889,000	947,000	1,013,000
	10% Percentile	563,000	586,000	627,000	672,000	718,000	767,000	811,000	861,000	918,000	979,000
	90% Percentile	592,000	617,000	659,000	706,000	759,000	808,000	860,000	919,000	979,000	1,049,000
Domestic Wells											
	Mean	85,000	88,000	95,000	102,000	109,000	116,000	124,000	132,000	141,000	151,000
	10% Percentile	84,000	87,000	93,000	100,000	107,000	114,000	121,000	129,000	138,000	147,000
	90% Percentile	87,000	90,000	97,000	103,000	111,000	119,000	127,000	135,000	145,000	156,000
Industrial											
	Mean	475,000	476,000	476,000	476,000	477,000	478,000	481,000	484,000	489,000	490,000
	10% Percentile	461,000	462,000	459,000	459,000	460,000	462,000	458,000	466,000	468,000	467,000
	90% Percentile	490,000	491,000	493,000	494,000	494,000	496,000	503,000	503,000	510,000	513,000
Agriculture											
	Mean	8,766,000	8,774,000	8,791,000	8,754,000	8,821,000	8,788,000	8,799,000	8,794,000	8,749,000	8,786,000
	10% Percentile	8,277,000	8,283,000	8,347,000	8,211,000	8,280,000	8,248,000	8,235,000	8,193,000	8,140,000	8,162,000
	90% Percentile	9,275,000	9,289,000	9,276,000	9,273,000	9,400,000	9,373,000	9,340,000	9,383,000	9,410,000	9,470,000
Total for All Sectors											
	Mean	9,905,000	9,940,000	10,004,000	10,021,000	10,144,000	10,169,000	10,240,000	10,300,000	10,326,000	10,440,000
	10% Percentile	9,384,000	9,418,000	9,526,000	9,441,000	9,563,000	9,590,000	9,625,000	9,650,000	9,664,000	9,754,000
	90% Percentile	10,444,000	10,487,000	10,524,000	10,575,000	10,764,000	10,795,000	10,830,000	10,941,000	11,043,000	11,187,000

Note: Refer to Appendix F for details on the assumptions used to define the range of values for the climate change variables.

- *Mean – the average demand generated by the uncertainty analysis using Monte Carlo simulation*
- *10th percentile demand – represents the statistical "lower-end" of the range of possible demand based on the uncertainty analysis; the demand that is exceeded 90 percent of the time based on the results of the Monte Carlo simulation.*
- *90th percentile demand - represents the statistical "upper-end" of the range of possible demand based on the uncertainty analysis; the demand that is exceeded 10 percent of the time based on the results of the Monte Carlo simulation.*

Table 11. Water Conservation Scenario: Statewide Water Demand (Acre Feet)

Sector		2007	2010	2015	2020	2025	2030	2035	2040	2045	2050
Municipal Systems											
	Mean	539,000	560,000	583,000	611,000	638,000	663,000	687,000	711,000	738,000	769,000
	10% Percentile	531,000	551,000	574,000	602,000	628,000	650,000	673,000	693,000	721,000	746,000
	90% Percentile	547,000	568,000	591,000	622,000	649,000	675,000	701,000	728,000	756,000	794,000
Domestic Wells											
	Mean	80,000	83,000	87,000	91,000	95,000	99,000	103,000	107,000	111,000	116,000
	10% Percentile	79,000	82,000	86,000	90,000	94,000	97,000	101,000	104,000	108,000	113,000
	90% Percentile	81,000	84,000	88,000	92,000	97,000	101,000	105,000	109,000	113,000	119,000
Industrial											
	Mean	423,000	424,000	415,000	406,000	396,000	389,000	379,000	370,000	363,000	357,000
	10% Percentile	414,000	413,000	405,000	396,000	384,000	376,000	365,000	358,000	348,000	343,000
	90% Percentile	433,000	434,000	425,000	417,000	408,000	401,000	391,000	383,000	378,000	370,000
Agriculture											
	Mean	7,695,000	7,684,000	7,421,000	7,158,000	7,003,000	6,864,000	6,728,000	6,593,000	6,586,000	6,606,000
	10% Percentile	7,481,000	7,452,000	7,177,000	6,917,000	6,731,000	6,569,000	6,405,000	6,215,000	6,238,000	6,242,000
	90% Percentile	7,912,000	7,914,000	7,654,000	7,418,000	7,282,000	7,164,000	7,048,000	6,946,000	6,945,000	6,981,000
Total for All Sectors											
	Mean	8,737,000	8,751,000	8,505,000	8,267,000	8,133,000	8,015,000	7,897,000	7,781,000	7,798,000	7,847,000
	10% Percentile	8,506,000	8,498,000	8,242,000	8,004,000	7,838,000	7,692,000	7,544,000	7,370,000	7,415,000	7,444,000
	90% Percentile	8,974,000	9,001,000	8,758,000	8,549,000	8,436,000	8,342,000	8,245,000	8,166,000	8,193,000	8,264,000

Notes:

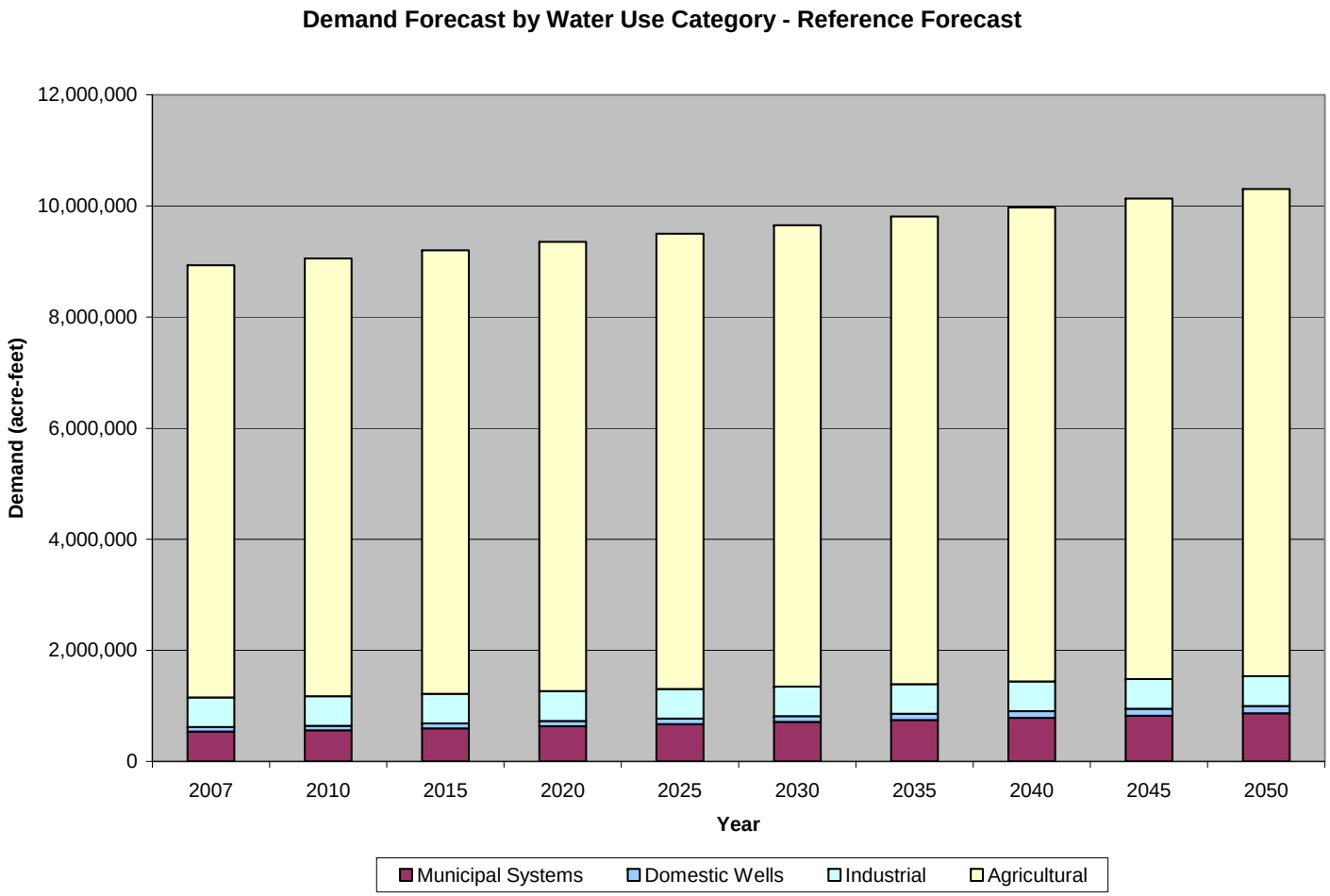
- *Note: Refer to Appendix F for details on the assumptions used to define the range of values for the water conservation variables.*
- *Mean – the average demand generated by the uncertainty analysis using Monte Carlo simulation*
- *10th percentile demand – represents the statistical "lower-end" of the range of possible demand based on the uncertainty analysis; the demand that is exceeded 90 percent of the time based on the results of the Monte Carlo simulation.*
- *90th percentile demand - represents the statistical "upper-end" of the range of possible demand based on the uncertainty analysis; the demand that is exceeded 10 percent of the time based on the results of the Monte Carlo simulation.*

This page intentionally left blank.

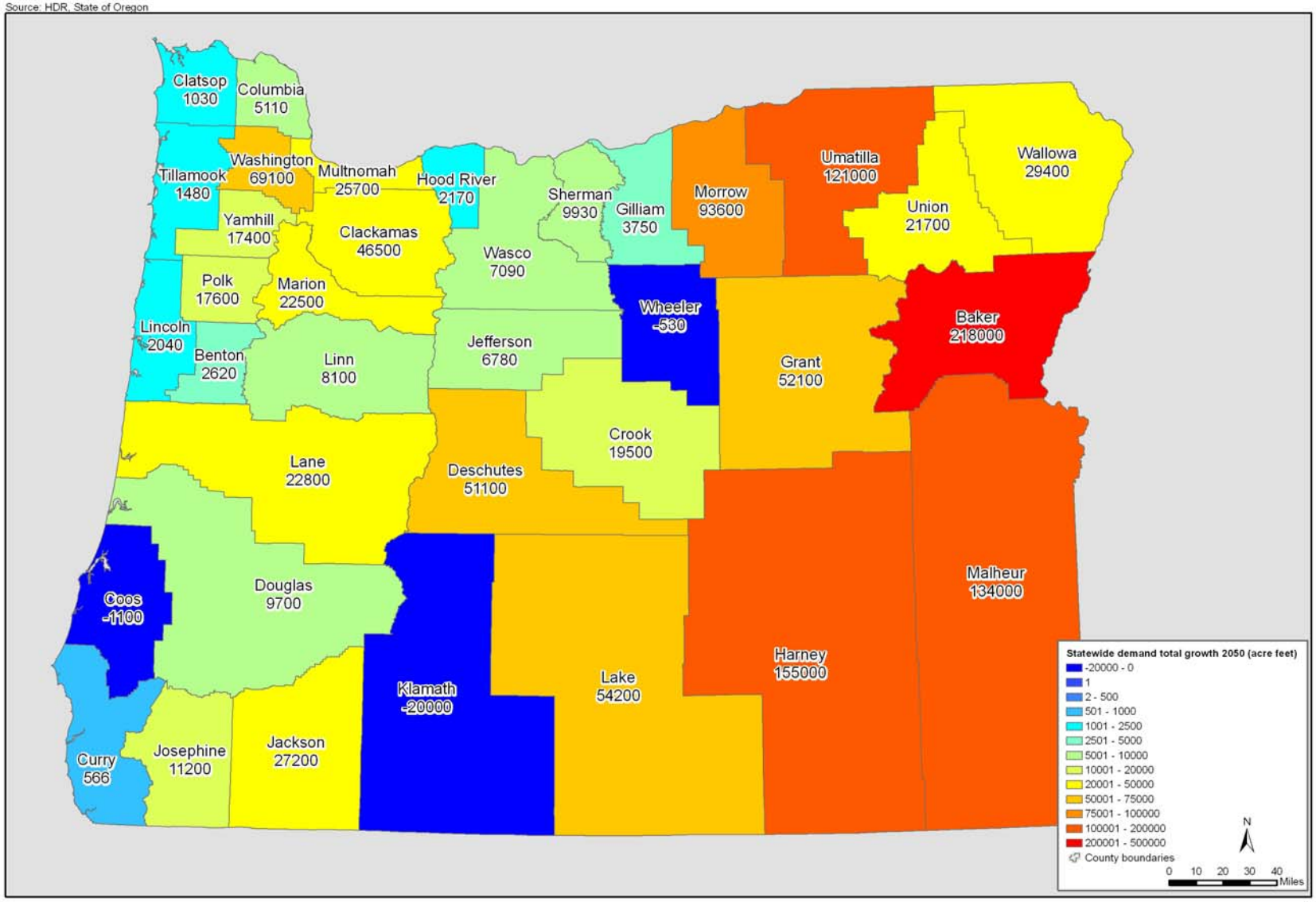
Section 4 Figures

This page intentionally left blank.

Figure 5. Demand Forecast by Water Use Category – Reference Forecast



Source: HDR, State of Oregon

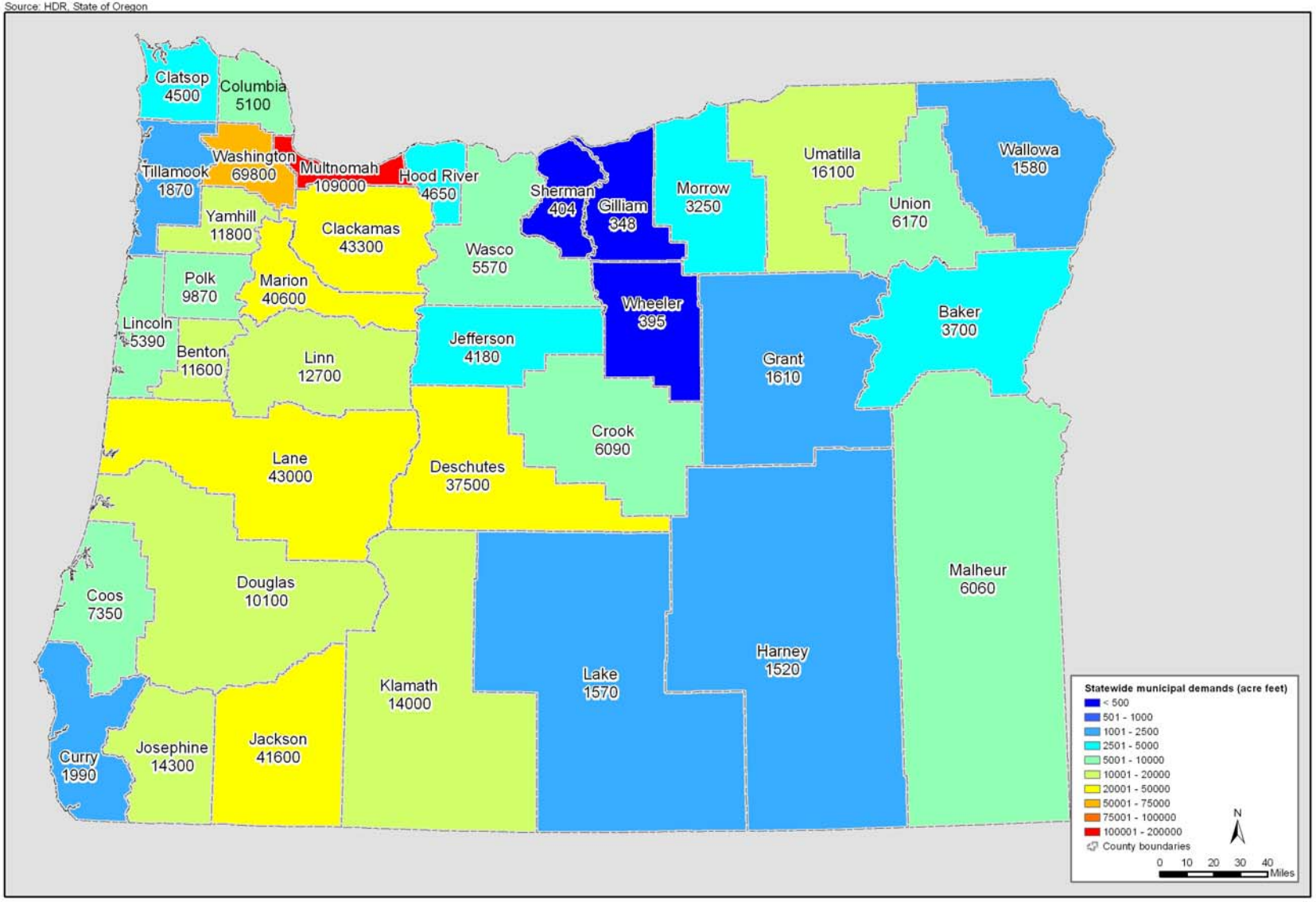


Statewide Total Water Demand Growth for 2050: Distribution by County

FIGURE 6

HDR ONE COMPANY | *Many Solutions*

Source: HDR, State of Oregon

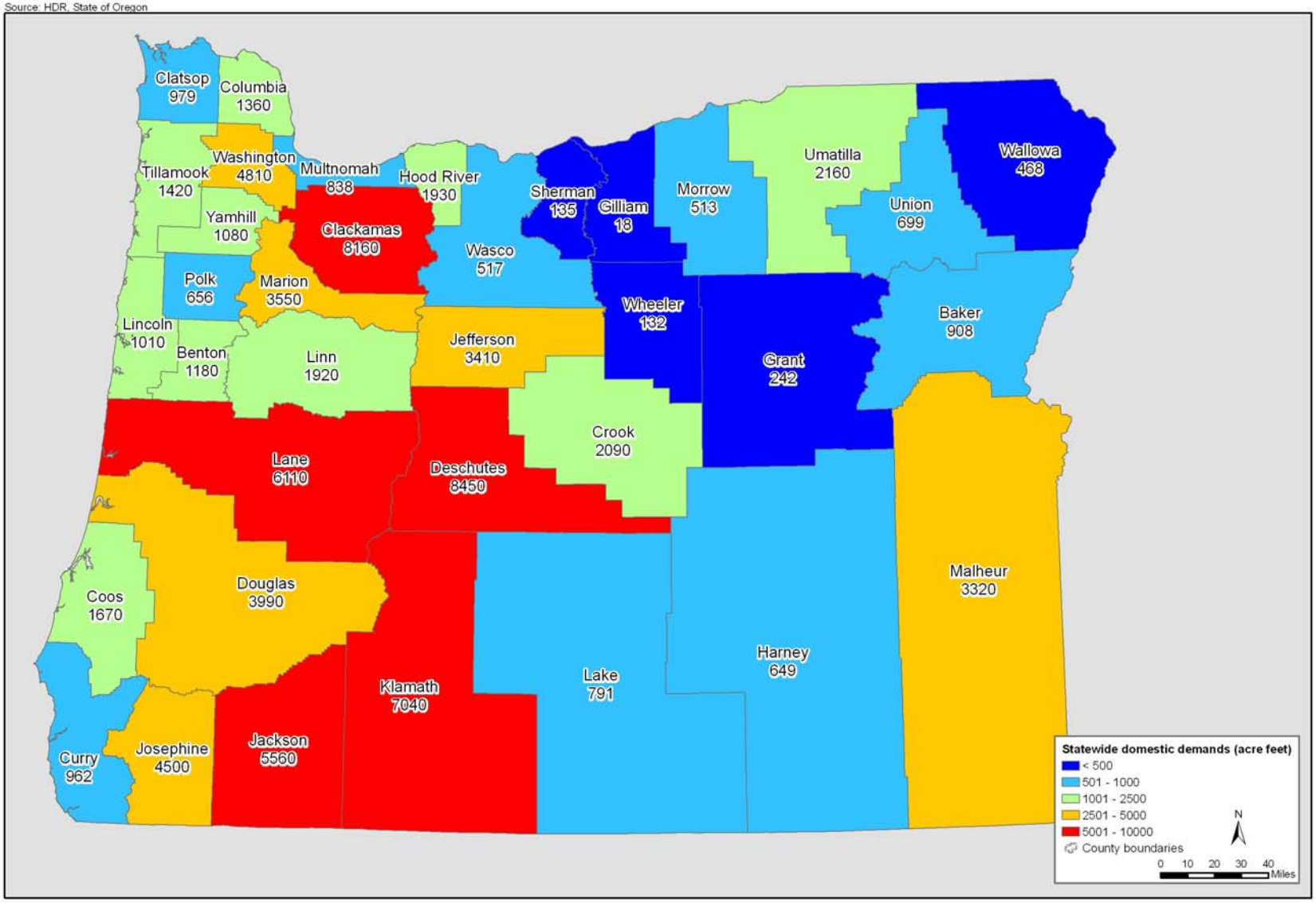


Municipal Water Demand by County - Reference Forecast (2010)

FIGURE 7

HDR ONE COMPANY | *Many Solutions*

Source: HDR, State of Oregon

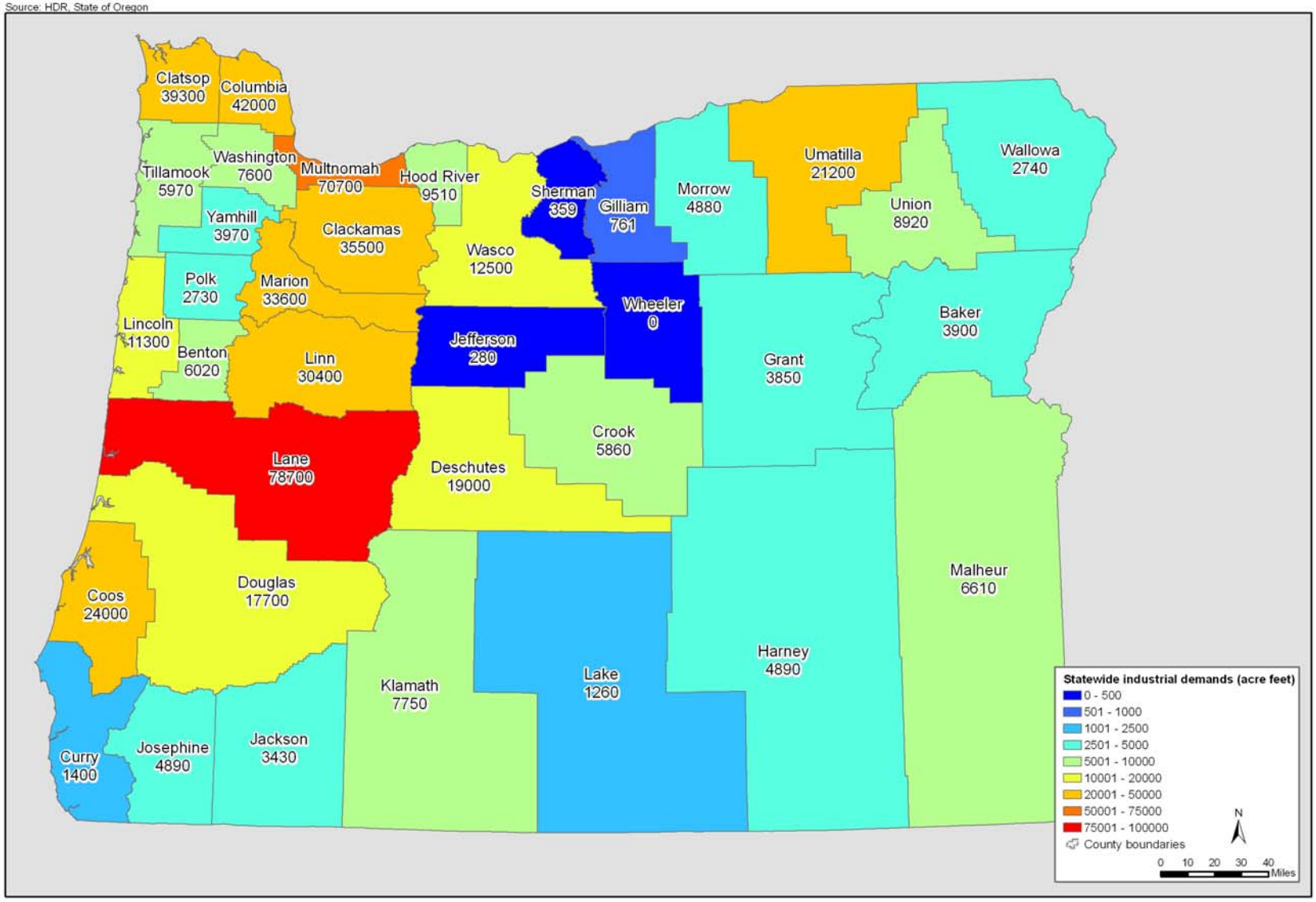


Domestic Well Water Demand by County - Reference Forecast (2010)

FIGURE 8

HDR ONE COMPANY | *Many Solutions*

Source: HDR, State of Oregon

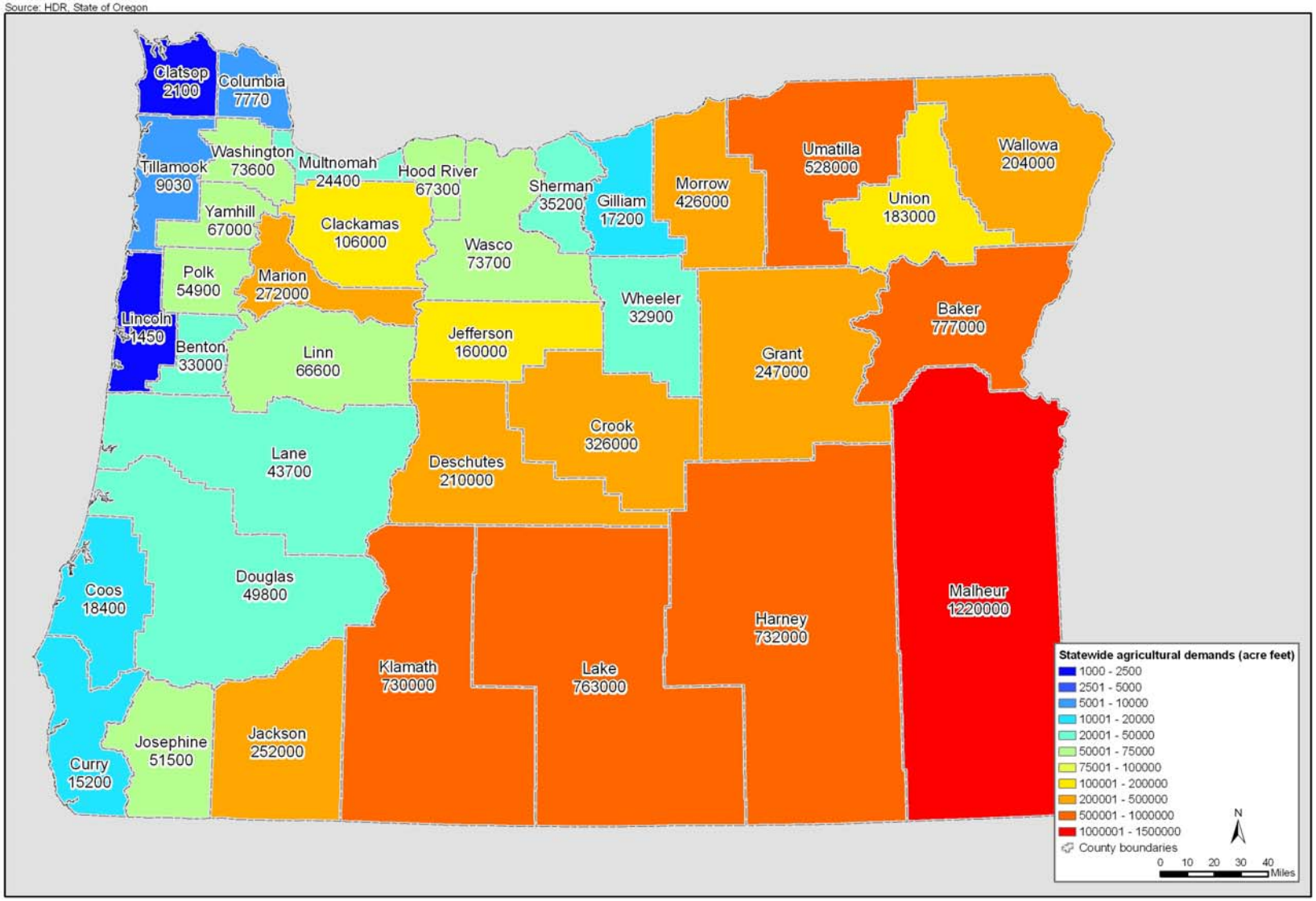


Self-supplied Industrial Water Demand by County - Reference Forecast (2010)

FIGURE 9

HDR ONE COMPANY | *Many Solutions*

Source: HDR, State of Oregon

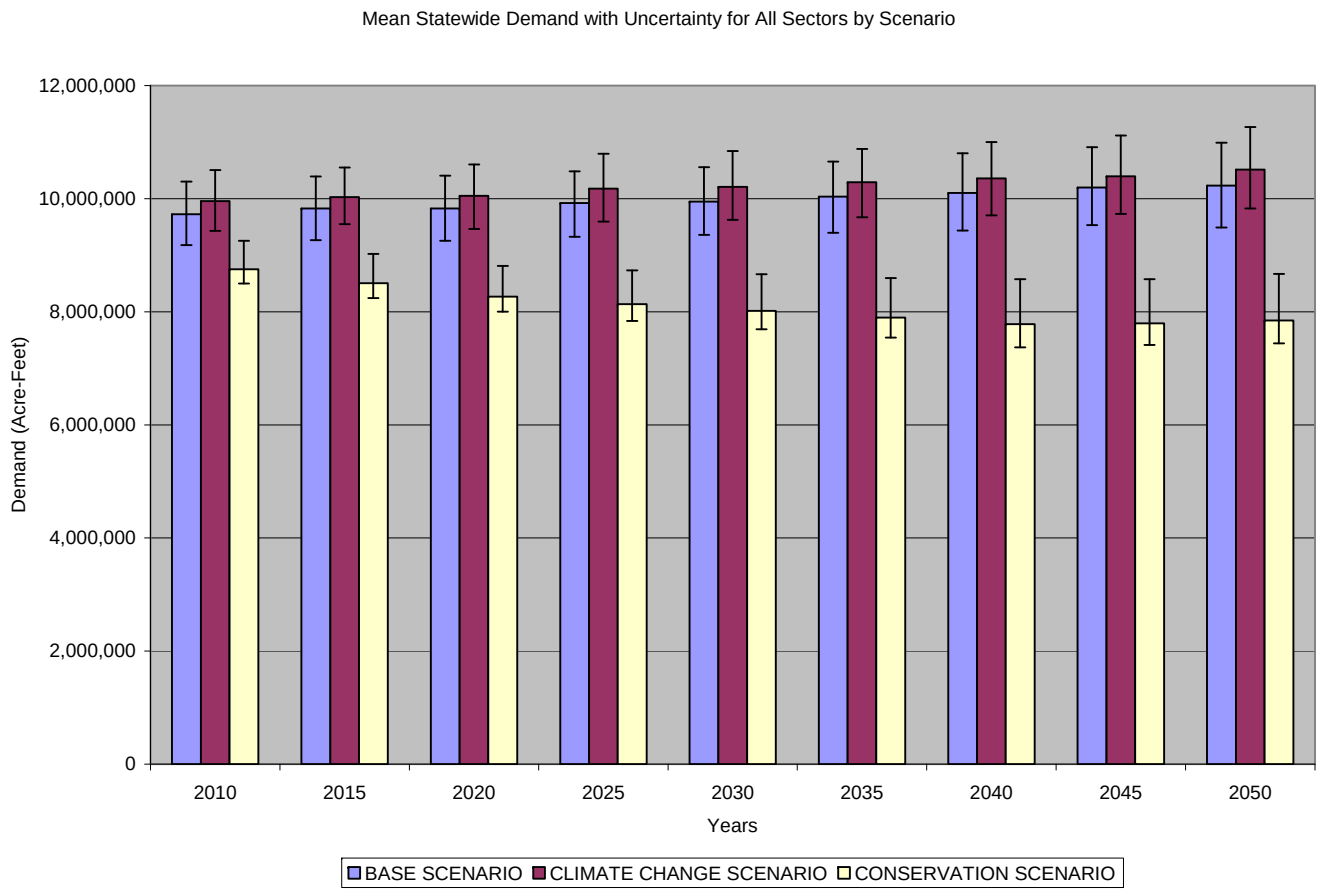


Statewide Agricultural Water Demand for 2010: Distribution by County

FIGURE 10

HDR ONE COMPANY | *Many Solutions*

Figure 11. Scenario Analysis Comparison of Statewide Demands with Uncertainty Range



Note: Whisker markers show the range of uncertainty in the demand forecast for each scenario; the whiskers represent the 10th-percentile and 90th-percentile values for demand (e.g. 10th-percentile is the lower whisker bar and is the value with 90 percent probability that demand is higher)

This page left intentionally blank.

5.0 Instream Uses

Sections 3.0 and 4.0 focused on water demand forecast for the out-of-stream (consumptive) water use categories. The two instream demands considered in this study and discussed in this section include: (i) hydropower and (ii) instream ecological uses. Demands for instream flow are based on an amount of water to be left in the stream as opposed to an amount of water that is removed from the stream for consumptive uses.

5.1 Hydropower

5.1.1 Definition

The focus of this component is on commercial hydropower from facilities owned or operated by federal agencies and public or private utilities. Hydropower (hydroelectricity) is generated from a turbine and generator installed either in or adjacent to a dam or in pipelines (penstocks). The energy from the water is converted to mechanical and then electrical energy. Hydropower projects are generally operated in a run-of-river or storage mode, as summarized below:

- Run-of-river (in-channel) – utilizes the flow of water within the natural range of the river, requiring little or no impoundment. Run-of-river projects use the natural flow of the river and produce relatively little change in the stream channel and stream flow.
- Diversion hydropower – a diversion takes a portion of the river through a canal or penstock, but may require a small dam to divert a portion of the river flow. This provides a lesser impact to the stream flow than a storage project.
- Storage project - impounds and stores water during high-flow periods to augment the water available during low-flow periods, allowing the flow releases and power production to be more constant

Another emerging source of hydropower is the class termed micro-hydro, which generate on the order of 100 kilowatts or less. Turbines are typically installed within water transmission lines and does not affect the source of water itself (i.e. stream flows), and for this reason are not considered explicitly for this project.

Water demand associated with hydropower is directly related to the demand for power (more specifically demand for electricity and/or renewable energy). Therefore, for the purposes of this project, the water demand for hydropower will be discussed in terms of the demand for hydropower. Furthermore this project focuses on how this energy demand is associated with larger storage projects (typically those with 1 megawatt of generation capacity or more) because of their greater impact on stream flow conditions and potential water availability or timing. Run-of-river and diversion facilities do not have as significant an impact on water demand and water availability and timing issues as do storage projects.

5.1.2 Methodology

It is beyond the scope of this project to do a comprehensive market/economic analysis for hydropower needs. Hydropower is unique among the water use categories in this project in that

regional power demands outside the state impact the power generation needs within the state because of power trading and transmission agreements. Furthermore, while the overall quantity of power demands can be assessed, associating specific projects to meet these demands introduces another order of complexity. For example, new hydropower demands can be met by expanding the capacity of existing facilities or creating new facilities altogether. Power transmission issues also play a significant factor in where new hydropower would be developed and the defined power market areas served by utilities.

For these reasons, the approach is to inventory current hydropower facilities related to dams/reservoirs and review qualitative factors that could affect the overall demand for increasing or decreasing hydropower.

The inventory of existing hydropower facilities was extracted from databases maintained by Oregon Water Resources Department and cross-referenced with Federal Energy Regulatory Commission (FERC) data. **Appendix E** includes the full data tables compiled for the inventory.

To account for future hydropower demand, the primary reference is the work that Department of Energy (DOE) – Idaho National Engineering Laboratory (INL) began in 1998. The purpose was to begin determining the undeveloped potential hydropower resources. INL completed the preliminary assessment of potential hydropower resources in February 1990 and DOE has continued these resource assessment activities under an interagency hydropower resource assessment team. The goal is to assemble a resource database of all potential hydropower sites for use as a planning tool to determine the viable national hydropower potential. The database include sites in Oregon.

5.1.3 Data Sources

The data sources used in this analysis, and the assumptions made with regard to the use of this data, are described below.

- **Hydroelectric Facilities Inventory – Oregon Water Resources Department.** OWRD maintains a spreadsheet that includes a list of hydroelectric facilities that have a hydroelectric license or a power claim with Oregon. The spreadsheet does not include federal facilities. The spreadsheet includes information on facility name, water rights permit number, stream name, basin, location, FERC status, and hydroelectric information (kilowatt, horsepower, flow capacity). The data does not indicate the type of facility (storage project, diversion, wave project, etc.). The spreadsheet was provided by Mary Grainey, OWRD. **Appendix E** includes the list of facilities in the spreadsheet that are noted as having at least 1 megawatt of generation capacity.

- **Dam Inventory – Oregon Water Resources Department – obtained from Oregon GIS spatial clearinghouse.** OWRD maintains a database with dam facilities that require their inspection (dams that are 10 feet high or have storage capacities of 9.2 acre-feet or greater). Information includes facility name, location (TRS, basin county), size (height and volume), and associated water rights, owner type, purpose of use, discharge. The database does not include information on hydroelectric capacity but does include discharge and dam height information. The database was queried for those that have

hydroelectric as a beneficial use and those that do not. Those facilities that have hydroelectric as at least one of the purposes of use are listed in **Appendix E**.

For the purposes of this project, data from the Oregon GIS spatial clearinghouse was used. Metadata is presented at:
http://www.oregon.gov/DAS/EISPD/GEO/docs/metadata/ordams.htm

The most up-to-date information is available from OWRD website:
http://apps.wrd.state.or.us/apps/sw/dam_inventory/dam_inventory.php

- **Facility Licensing Data - Federal Energy Regulatory Commission.** FERC is an independent agency that regulates the interstate transmission of electricity, natural gas, and oil. With respect to hydropower, FERC's responsibilities include issuance of licenses for the construction of a new project, issuance of licenses for the continuance of an existing project (relicensing), and oversight of all ongoing project operations, including dam safety inspections and environmental monitoring. Spreadsheets listing licensed projects, preliminary permits, and exemptions were reviewed. Spreadsheets can be downloaded at: http://www.ferc.gov/industries/hydropower.asp

- **Renewable Energy Annual (2006).** A series of annual publications on renewable energy by the Energy Information Administration (EIA). The information is focused on historical hydropower use by different categories, including conventional hydropower. http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html

- **U.S. Hydropower Resource Assessment Final Report (and Oregon Resource Assessment), Idaho National Laboratory (1998).** Information includes assessment of undeveloped hydropower based on the methodology developed by INL. The assessment defines hydropower potential for projects currently with hydropower developed, projects currently without power facilities, and projects without any developed facilities (impoundments or diversion structure). Details of the methodology and associated reports are available at: http://hydropower.inl.gov/resourceassessment/

5.1.4 Summary of Hydropower Inventory

Oregon had a net capacity of over 8,300 MW (37,800,000 KWH generation) of conventional hydroelectric power generation capacity as of 2006 according to the Renewable Energy Annual 2006 report (released in 2008) by the EIA.

The hydropower resource assessment completed in 1998 by DOE-INL focused on facilities having a potential capacity of 1 MW and above. DOE then completed an assessment of low head (less than 30 ft) and low power (less than 1 MW) resources in 2000. The focus of this discussion is the high head high capacity facilities. The DOE-INL assessment considered three classes of facilities:

- With Power – Developed hydropower site with current power generation, but the total hydropower potential has not been fully developed. Only the undeveloped hydropower potential is discussed in the report.

- Without Power – Developed site without current power generation. The site has some type of developed impoundment or diversion structure, but no developed hydropower generating capability.
- Undeveloped – The site does not have power generation capability nor a developed impoundment or diversion structure.

A total of 222 projects were identified and assessed for their undeveloped hydropower potential. Table 12 summarizes the findings of the Oregon-specific assessment by INL. The total name plate capacity based on infrastructure considerations only was estimated to be ~3,500 MW of undeveloped capacity, while the adjusted capacity was estimated to be ~2,200 MW. The modeled (or adjusted) capacity was based on considering environmental attribute data to generate an overall project environmental suitability factor (PESF). A combination of attributes can result in a lower suitability factor because multiple environmental considerations would reduce the likelihood that a site may be developed to its physical potential.

Table 12. Summary of Undeveloped Hydropower Potential (taken from INL, 1998)

Category	Number of Projects	Name Plate Capacity (MW)	Assessment Adjusted Capacity (MW)
With Power	3	~44	~11
Without Power	101	~2,500	~1,900
Undeveloped	118	~950	~320
Totals:	222	~3,500	2,200

Due to the issues discussed earlier, it is difficult to allocate this statewide hydroelectric generation potential into specific projects or facilities across the state. However, assuming that it will be more feasible to expand or add hydropower infrastructure to existing reservoirs and hydropower projects, the OWRD databases reviewed can be used to determine which administrative basins are more likely to be impacted by expanded hydropower demand in the state.

OWRD has over 1,100 dams in its regulated dam inventory database (dams taller than 10 feet or with storage volume greater than 9.2 acre-feet), with 57 of those dams having hydroelectric generation as a beneficial use. The facility records from this database were not cross-referenced with actual power generation capacity information. However, a power generation capacity potential was calculated using the listed dam height and maximum discharge capacity[2]. These power generation surrogate values are not intended to quantify the actual power generation

[2] A surrogate electric generation capacity was calculated using the listed dam height and maximum discharge rate multiplied by a unit conversion factor and 50% "efficiency factor."

potential, but rather as a way to semi-quantitatively assess the facilities that could have the potential to generate more significant quantities of power based on their existing size. **Appendix E, Table E-1** list the 57 dams having hydroelectric generation as a beneficial use and the remaining 172 dam facilities with a surrogate hydroelectric capacity of at least 1 MW.

OWRD has a separate inventory of over 150 hydroelectric facilities that it permits or licenses. The inventory includes projects that are not necessarily associated with a reservoir (e.g., diversion, pumped storage, or pipeline). This inventory does include information on estimated hydroelectric power generation capacity. The total generation capacity of facilities on the list is over 2,300 MW. From this list, 53 facilities have a listed capacity greater than 1 MW (not including the Idaho Power Company's Snake River projects). However, this inventory does not include federal projects. Most of these facilities are located in the Willamette, Umpqua, Rogue, and Deschutes basins. There are also a limited number of facilities in Sandy, Owyhee, Hood, Umatilla, and Wallowa basins. **Appendix E, Table E-2** lists the facilities.

5.1.5 Trends and Issues in Hydropower Demand

Several key factors affect the demand for hydropower. Opponents argue that hydropower can harm aquatic environments and impact instream needs. Concerns for hydropower's impacts to the aquatic environment have direct implications to the relicensing process for FERC projects, as well as operations of federal projects through Endangered Species Act (ESA) requirements. EIA information showed a decrease in the hydroelectric generation's share of total utility generation from 1970 through 2000, as generation from coal-fired and nuclear generation increased. However, as energy demands and concerns about climate change continue to increase, hydropower has the potential to become an important energy alternative because of its status as a renewable energy source that does not pollute the air or increase emissions of greenhouse gases. At the same time, other renewable energy sources such as wind, solar, and geothermal are also gaining in popularity to compete with hydropower.

Another key issue with hydropower generation and demand is its susceptibility to climate conditions. Precipitation is a key factor in the ability of hydroelectric facilities to reliably produce generation capacity. Actual power generation fluctuates directly with the amount of precipitation that occurs. During drought conditions power generation can be reduced significantly over the duration of the drought. Therefore, climate trends will dictate where and how much new or expanded hydropower will occur.

Perhaps the biggest factor in the expansion of hydropower in Oregon is the Endangered Species Act requirements. ESA applies to all federally-owned projects, as well as the FERC relicensing process. The operations of federal facilities will be greatly affected by the biological opinions issued by National Marine Fisheries Service and the costs associated with resulting operational constraints imposed by ESA requirements. Costs associated with mitigating for environmental impacts have caused hydro-electric rates to increase in the past and industrial customers to consider other sources of electricity.

With these issues in mind, it is difficult to predict the trend for hydropower without conducting a more rigorous market analysis for the region as a whole. The overall demands for hydropower will then need to be evaluated in more detail against the existing facilities

5.2 Instream Demand for Ecological Needs

5.2.1 Definition

OWRD defines instream flow requirements using existing instream water rights and scenic water way designations. These requirements are typically defined on a monthly basis. OWRD uses these monthly values in the Water Availability Reporting System (WARS) to determine whether there is available water for approving new water right permits. Flow is calculated in cubic feet per second (cfs) for both 50% and 80% exceedance natural flow levels.

Water availability and instream requirements are managed and accounted for in terms of "water availability basins" or WABs. To date OWRD has delineated 2221 WABs. WABs have been delineated above the mouths of significant tributaries, on main channels above significant tributaries and for all in-stream demands. Water availability is estimated at the downstream end or "pour point" of each WAB. WABs are nested so that each upstream WAB is included in a WAB downstream. For water to be available in a given WAB, it must be available in all other watersheds in which it is nested (i.e. downstream watersheds). A map of WABs and the pour points are shown in **Appendix E, Figure E-1**.

It was agreed by the state agencies that peak flow considerations would not be included in this phase of the demand assessment for instream flows. It was agreed peak flow considerations are applicable on a stream-by-stream basis and not appropriate for the basin-scale assessments and policy-level planning comparisons under this phase of the OWSCI project. OWRD plans to incorporate instream peak flow demands as part of a planned basin yield analysis.

5.2.2 Methodology

As stated above, instream flow demands are defined as existing instream water rights and scenic water way designations. Where WABs do not have an instream water right or other established flow requirement, an estimate of instream flow need is made using a fraction (or ratio) of the 50% exceedance natural flow levels in the same region. The fraction is based on the level of instream flows that have already been established in the "climate region." The fraction for each WAB is found by dividing the established instream water right by the 50% exceedance flow for each month.

As an example:

Instream Demand Ratio = Instream Water Right (ISWR)/Natural Stream Flow 50% (NSF)

Where:

- January ISWR = 1.00 cfs
- January NSF @ 50% exceedance = 1.63 cfs
- 1.00/1.63 = 0.61 or 61%
- Instream demand for January is 61% of the natural stream flow

Some administrative basins do not have sufficient data points (i.e., established instream water rights) to justify a basin wide approach. For example, Hood Basin has 11 instream water rights, Goose and Summer Lakes has 12, and Owyhee Basin has none. The solution is to average the monthly ratios over larger areas so that a statistically valid number of instream flows are available to calculate the fractions. These larger areas – termed "instream regions" for this project – are based on grouping appropriate administrative basins that have similar climates. The resulting ratios are then applied to streams in the corresponding administrative basins within the instream regions that do not have existing water rights.

To calculate the ratios, administrative basins are grouped into the following four instream regions (refer to Figure 12):

- Coastal Region: Basins 1, 17 and 18
- Western Interior Region: Basins 2, 3, 15 and 16
- Central Region: Basins 4, 5, 6, and 14
- Eastern Region: Basins 7, 8, 9, 10, 11, 12 and 13

Table 13 lists the average instream demand ratios for the instream regions. Figure 13 shows graphically how the average instream demand ratio differs among the regions. The differences among the curves are attributable to the different natural streamflow patterns as well as how the actual instream water rights were defined in the region.

Table 13. Instream Demand Ratio for Instream Regions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coastal	58%	57%	65%	83%	89%	91%	92%	96%	97%	97%	81%	59%
Western Interior	50%	49%	55%	58%	64%	71%	75%	81%	83%	89%	75%	51%
Eastern	73%	70%	61%	48%	47%	56%	70%	77%	80%	82%	78%	75%
Central	63%	55%	54%	55%	55%	59%	69%	75%	73%	78%	74%	68%
State	63%	61%	64%	71%	75%	78%	83%	87%	89%	91%	81%	66%

To actually quantify the instream demand within the administrative basin, all of the "pour points" or discharge points out of the basin are identified. The total sum of the 50% exceedance flow multiplied by the instream demand ratio is then calculated for these pour points. Owyhee Basin does not have a separate forecasted instream demand because its discharge point (pour point) is to the Malheur Basin. The forecasted instream demand for Malheur Basin includes Owyhee Basin. There are no existing instream water rights defined for Owyhee Basin. The instream demand based on the existing instream water rights associated with the pour points was also calculated for comparison purposes with the method. In most cases, the method resulted in larger instream demands. **Appendix E, Table E-3** summarizes the data and calculations for each administrative basin.

This page left intentionally blank.

Figure 12. Grouping of Administrative Basins into "Instream Regions"

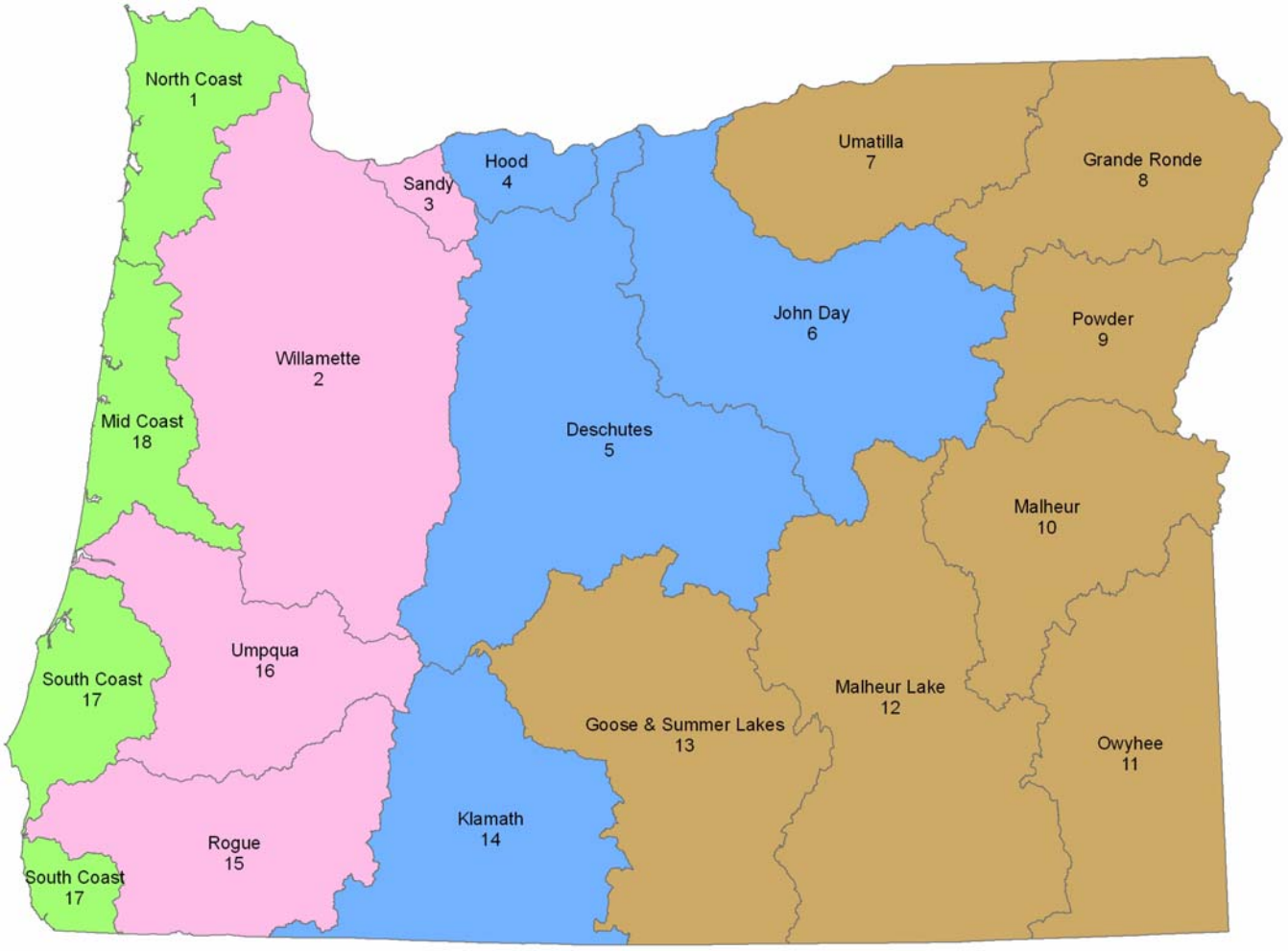
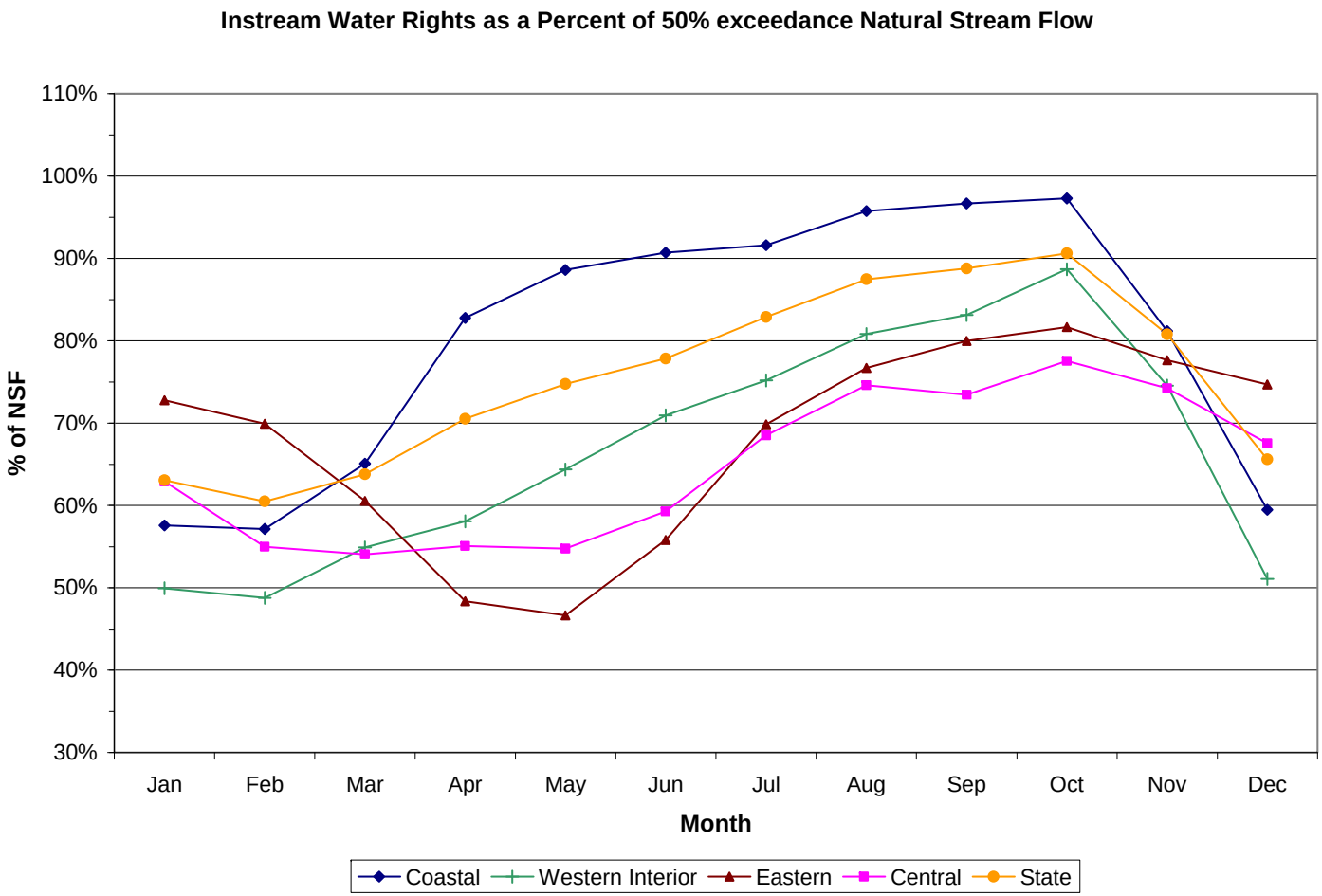


Figure 13. Monthly Instream Demand Ratio for Instream Regions



5.2.3 Data Sources

The data sources used in this analysis, and the assumptions made with regard to the use of this data, are described below.

- **Water Rights Information System, Oregon Water Resources Department.** Queried the existing instream water rights and scenic water way flows for each water availability basin (WAB).
- **Water Availability Reporting System, Oregon Water Resources Department.** Queried the 50% exceedance natural streamflows determined by OWRD. The pour points (WABs with a discharge point from the administrative basin) of each administrative basin were also identified from this database.
- **Determining Surface Water Availability in Oregon.** 2002. Oregon Water Resources Department. Information used to supplement database information.

5.2.4 Results

The total forecasted instream demand on a volumetric basis is determined for each administrative basin by summing the contribution at each pour point. The results for the annual total, July and January months are shown in Table 14, which also shows the out-of-stream demand for 2010 based on the reference forecast in the forecasting tool. Figure 13 show the relative magnitude of the forecasted instream demand by administrative basin.

The Willamette Basin has by far the largest instream annual demands based on this method with over 11 million acre feet annually. The coastal basins, Deschutes Basin, Rogue, Umpqua, and Klamath basins have the next highest annual instream demands on the order of one to four million acre-feet. The eastern basins have significantly less typically with less than one million acre-feet annually.

Because of the different streamflow patterns in the basin, the ratio of the July to January instream demands are typically lowest in the wetter basins and highest in the eastern or drier basins. The smaller the percentage or ratio implies a smaller instream demand in the summer than the winter.

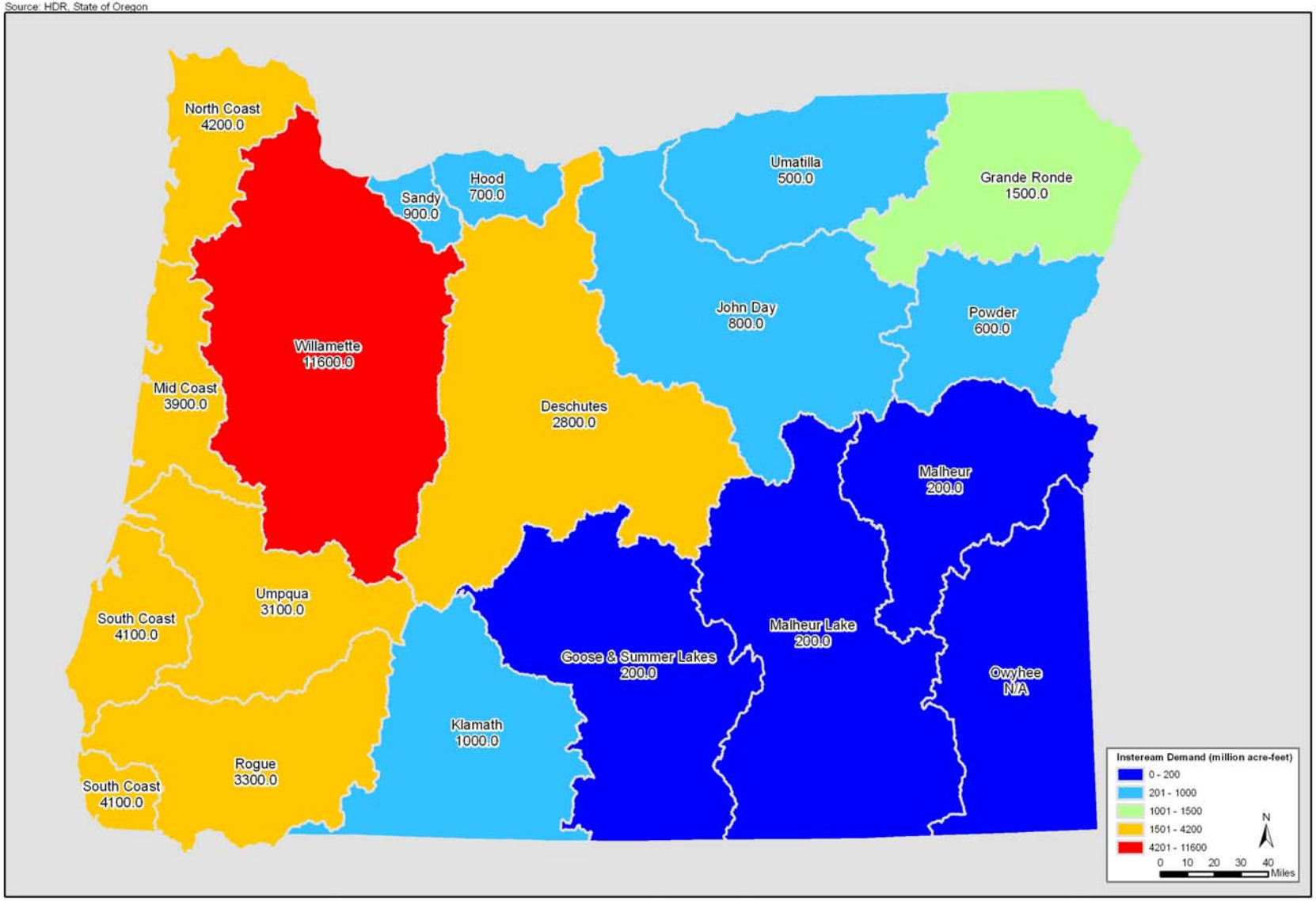
The ratio of instream demand to out-of-stream demands was calculated for each basin. This does not tell the complete story without the water yield or water availability, but it does indicate how the two types of demands compare. The higher the ratio means more out-of-stream demand relative to instream demand. The results show that several of the eastern region basins with high agricultural demands have the highest ratios: John Day, Powder, and Malheur basins. Of course these comparisons do not consider local stream conflicts between instream and out-of-stream demands.

Table 14. Total Instream Demand by Administrative Basin (acre-feet)

Administrative Basin	Annual	July	January	Ratio July/Jan	Annual Out-of-stream Consumptive Demand (2010)*	Annual Ratio (out-of-stream/ instream)
1 - North Coast	4,214,000	86,000	668,000	13%	620,000	14%
2 - Willamette	11,560,000	370,000	1,578,000	23%	2,558,000	22%
3 - Sandy	915,000	44,000	98,000	45%	38,000	4%
4 - Hood	670,000	38,000	79,000	48%	338,000	50%
5 - Deschutes	2,772,000	219,000	225,000	97%	232,000	8%
6 - John Day	794000	30,000	48,000	62%	966,000	119%
7 - Umatilla	459,000	15,000	48,000	32%	350,000	75%
8 - Grande Ronde	1,521,000	119,000	85,000	140%	207,000	13%
9 - Powder	575,000	40,000	28,000	143%	863,000	146%
10 - Malheur	203,000	8,400	11,000	73%	246,000	121%
11 – Owyhee**	N/A	N/A	N/A	N/A	62,000	N/A
12 - Malheur Lake	230,000	11,000	12,000	91%	70,000	31%
13 - Goose & Summer Lake	248,000	9,700	12,000	78%	51,000	21%
14 - Klamath	1,033,000	83,000	90,000	92%	780,000	75%
15 - Rogue	3,324,000	124,000	402,000	31%	974,000	29%
16 - Umpqua	3,064,000	86,000	442,000	19%	46,000	1%
17 - South Coast	4,096,000	69,000	655,000	10%	566,000	14%
18 - Mid Coast	3,860,000	82,000	622,000	13%	90,000	2%

** Based on the reference forecast in the forecasting tool.*
*** Owyhee Basin does not have a separate forecasted instream demand because its discharge point (pour point) is to the Malheur Basin. The forecasted instream demand for Malheur Basin includes Owyhee Basin. There are no existing instream water rights defined for Owyhee Basin.*

Source: HDR, State of Oregon



Surrogate Instream Demand for Ecological Use by Administrative Basin

FIGURE 14

HDR
ONE COMPANY | *Many Solutions*

This page left intentionally blank.

6.0 Future Application and Development

6.1 Summary of Findings

Key findings from the project include:

- The out-of-stream demands in the state are projected to increase significantly over the next 20 and 50 years driven by continuing demands from agriculture, population growth and industry. An increase of over 1 million acre-feet annual water demand is forecasted over the next 40 years.

- Irrigated agriculture currently accounts for the greatest demands statewide with over 85% of the overall out-of-stream demand, as well as accounting for ~75% of the forecasted increase in demand over the next 40 years. Baker, Gilliam, Grant, Harney, Morrow, Sherman, and Umatilla counties in particular have the potential to see the most significant increases in agricultural water demands.

- Population growth is expected to be the key driver for increasing municipal water demand in several key counties, including Clackamas, Deschutes, Josephine, Lincoln, Polk, Washington, and Yamhill counties.

- Water conservation can significantly reduce water demands in all water use categories. Using fairly aggressive conservation assumptions, the results showed total water savings of approximately 25% when comparing the reference forecast and mean forecast for the conservation scenario. On average this is equivalent to achieving a water savings on the order of 0.6% per year over the next 40 years. It should be noted that achievement of this level of conservation would require substantial changes in how the public uses water, as well as significant investments, i.e., funding to support infrastructure and management improvements.

- The climate change scenario modeled is preliminary in nature and additional study is needed to understand its impacts on a local and regional basis. For this study, climate change was assumed to have a moderate to fairly extreme effect on water use factors (i.e., increase of 8-18% on average on outdoor per capita water use and irrigation requirements over 40 years). The results showed less than 3% increase in the average demand when comparing the reference forecast and mean forecast for the climate change scenario. Nevertheless, climate change is considered an important factor in how future water demands unfold because of the uncertainty it poses on overall water demands in all of water use sectors – especially on agricultural demands.

- The findings from the demand forecast scenarios and the forecasting tool are useful for estimating the current magnitude and distribution of water demands, and understanding general trends for the purposes of policy discussions. However, the data gaps highlighted in this study indicate the need to understand the limitations of the model and the uncertainties associated with the demand forecast.

6.2 Forecasting Tool Modifications and Enhancements

One of the objectives of this project was to "provide a forecasting tool that can be used to examine alternative scenarios affecting future water needs." The forecasting tool has been structured so it can accommodate extensive data that affect water use, at the appropriate spatial resolution to assess a variety of planning scenarios. While this version has the capabilities to meet the objectives of the project, it is considered a "first-generation" version and there are improvements that can enhance the utility of the tool.

As noted previously, the modeling team encourages OWRD and stakeholders to compare these data, both internally within the model itself and externally with other data sources. This process can help to both assess model validity and understand model limitations to improve the forecasting tool.

As part of this application and validation process, three areas of modifications would allow more sophisticated applications for the forecasting tool:

- **Database update application.** The basic data and modeling approach used was designed to permit expanded and updated data to be input as OWRD continues with the OWSCI and related activities. A database application tool can be developed that can automatically update the base data in the forecasting tool upon receiving it from water providers or other sources.

- **Alternative geographic scales.** The model could be modified structurally to permit alternative geographic breakdowns throughout the state besides county or administrative basin. In this initial effort, the data acquired and input to the model is relatively limited, and the geographic scales reported cover only county and administrative basin levels.

- **Incorporating uncertainty analysis.** Due to budget constraints, the uncertainty analysis was conducted on the specific scenarios defined by the modeling team. The same Monte Carlo simulation functions used by the modeling team can be imbedded in the forecasting tool. Due to the complex calculations, some structural changes would be needed in the tool to make run times practicable. This type of added functionality would also require more advanced interpretation and analysis of input and output from the model.

Available funding limited the ability to include some of the following features considered to be enhancements:

- **User guide and documentation.** The first-generation version includes basic documentation to explain generally the components and functions of the forecasting tool. There are details and nuances in applying the tool that can be illustrated through additional documentation and examples, including "helpful hints" or "frequently asked questions."

- **Enhanced user interface (sorting and querying functions).** Basic sorting functions are included in the first-generation version of the forecasting tool. Revising the input parameters can be tedious for users wanting to evaluate more involved scenarios. An

enhanced user interface can be developed to allow more global-level changes as well as querying parameters for targeted updates. These can be completed in Visual Basic or other application compatible with the Excel format of the forecasting tool.

- **Output Tools.** The forecasting tool has summary output graphs for the different geographical scales and water use sectors. The output from the spreadsheet tool can be integrated with GIS and used to present more graphical and map-based outputs.

6.3 Priority Data Needs

The final objective of the project was to determine where key data are missing or inadequate, and to identify sources of uncertainty in water demand forecasting, in order to target available budget resources to improve water planning capabilities. The following recommendations are related to the key priority data needs derived from the "Data Limitations" discussions in Section 3 for each of the water use categories. As part of this process, other relevant studies have been identified that could help improve water planning capabilities.

- **Enhance OWRD's water use reporting system.** This recommendation integrates the key data gaps (data limitations listed in Section 3) with the need to develop an efficient process to collect and process the information. OWRD already has a program through the water use reporting system that can be enhanced to include appropriate data used in the forecasting tool, as well as for general water planning capabilities.
    - Part of this process should include continued outreach to water providers and stakeholders to increase participation in the water use reporting process to support forecasting updates.
    - More complete water use information from all sectors will reduce the uncertainty surrounding the input variables of the model. Key additional data for the water use categories include:
        - Municipal: water use by sector (e.g., residential, commercial/industrial, institutional); seasonal (monthly) water use.
        - Agricultural: acreage by crop group; seasonal (monthly) water use; estimates of system irrigation efficiency and conveyance efficiency.
        - Industrial: use patterns (daily/seasonal) by type of industry.
    - A standardized and streamlined data transfer system would be needed to make this process practicable for both OWRD and the water providers.
    - Leverage and support the work by USGS to compile water use information. Consider developing a similar and parallel process for Oregon that compiles information for the same major water use categories.
- **Conduct a study on trends in irrigated agriculture for the state.** A more robust and sophisticated economic analysis is needed to derive trends in irrigated agriculture. The

ability to forecast/predict changes in water demands for irrigated agriculture require highly complex and much more sophisticated methods than those possible under this project. Economic models are necessary to account for the "elasticity" in the myriad drivers that affect agriculture. Such a study should focus on defining the following characteristics in different regions across the state:

- Trends in conversion or expansion of irrigated lands.
- Trends in the type of crops grown.
- Factors considered in these two study areas could include water availability limits, climatic conditions, economic conditions, regulatory constraints, and land use policies.

- **Study urban-rural development patterns.** This study would focus on analyzing the development patterns and trends with respect to urban and rural densities which might impact water demands. Issues related to land use decisions and their impacts on water use could be studied. This is distinct from the study on trends in agriculture because it would focus on the urban-rural trends and how municipal and domestic well water use patterns are changing.

- **Develop a coordinated population forecasting program for the state.** The population estimates from the Office of Economic Analysis (OEA) has growth rates by county for incorporated and unincorporated areas. Population growth rates are desirable on a smaller geographical scale to allow more reliable population estimates at the scales used in the forecasting tool. A coordinated population forecasting program could be used to provide input (to OEA) on a scale such as the census block group or other smaller geographic unit.

- **Conduct a water use study for the self-supplied industrial sector.** The forecast for self-supplied industrial use is considered provisional. A detailed study on water use by different types of self-supplied industries would greatly improve the estimates and basis for the industrial demand. Further coordination with community and development planning agencies (counties and communities) is needed to make the forecasting process for this category more reliable.

- **Conduct a statewide water conservation potential assessment.** A statewide CPA would provide more quantitative basis for estimating how much water savings could be achieved with a range of conservation best-practices. The uncertainty analysis included generalized assumptions on potential water conservation savings for the municipal and agricultural sectors. These assumptions need to be refined based on more detailed assessment of existing water use practices and types of conservation activities available to water providers. This study is different than (but would enhance) the conservation inventory project conducted under OWSCI, which focused on collecting information on planned future projects. Information on conservation measures from water management and conservation plans required under Division 86 rules can be used as a starting point for estimating conservation potential.

- For the agricultural sector, irrigation practices, water use efficiency data and water conveyance efficiency data will be critical.
- For the municipal sector, system leakage and unaccounted-for-water and a database of current conservation practices are needed.
- The industrial sector water use study should also include an assessment of industrial-specific conservation activities.
- Leverage the work completed under the "Water Conservation Inventory" of the OWSCI project as a starting point for developing a conservation potential assessment. Recommendations from that study should be consulted for how that inventory can be applied and improved upon.

- **Conduct a study on local climate change impacts for the state.** The climate change scenario used three general zones within the state to attempt to define the different potential regional impacts across the state. Some recent studies are beginning to "translate" global and large-scale regional models to climate zones within the state. For example, the Climate Impacts Group from University of Washington is conducting some work for OWRD on streamflows in tributaries to the Columbia River using different global climate models. The Bureau of Reclamation has also completed work that down-scales climatic information from global climate models to local scales. Information from these and future studies could be used to refine the climate changes impacts assumptions and integrated into the forecasting analysis.

- **Complete hydrological study for ecological needs.** The instream demands were forecasted using *existing* instream water rights (and scenic water way flows) and their relationship to natural flow statistics. Some of the basins have relatively few instream water rights for this analysis and the methodology had to rely on a more regional area (i.e., greater scale than individual administrative basins) to derive the forecasted instream demands. This series of studies would be conducted for each administrative basin and include hydrological analysis of basin water yield. The studies could be done in conjunction with studies for instream flows, including peak flow analysis, for ecological needs. The instream flow studies would have to be conducted in specific reaches across the state to refine the methodology used in this study.

- **Conduct a hydropower potential assessment.** DOE completed a hydropower potential assessment across the country, including for the state of Oregon. A more focused and comprehensive market assessment for hydropower is needed to estimate the water demand associated with different hydropower categories for existing and new reservoir/storage facilities, installing new hydropower in existing facilities, and other infrastructure (e.g., micro-hydro in canals and pipelines). Forecasting hydropower demand is highly complex because of the many external economic, regulatory, and environmental drivers. For example, demand and supply for power in Oregon can be driven by market conditions in California.

- **Study to evaluate sources of supply.** As a follow-on to the water demand focus of this study, there is need to assess how water demands are being met by current sources of supply across the state, including water conservation. The other key component of the water supply question is the water availability study component of OWSCI which was not funded by the legislature, as well as the OWSCI study on potential aboveground and below ground storage sites. By understanding the relationship among demands, supplies, and water availability, the state can identify and understand water supply deficiencies in different parts of the state for planning and management purposes.

6.4 Integration with Water Management Planning Needs

The objectives of this project were to gain a better understanding of the water demands in the state, develop tools for assessing water demands, and identify data needs and next steps to improve water planning capabilities. As OWRD proceeds with OWSCI, the Department will work with water users, stakeholders, and the Legislature to determine how the water needs assessment documented in this report can best be coordinated with water supply planning activities. Additional questions will undoubtedly be identified that can be addressed, in part, through additional attention to the water needs assessment.

7.0 References

Cuenca, Richard H., et al. 1992. Oregon Crop Water Use and Irrigation Requirements. Publication Miscellaneous 8530. Oregon State University Water Resources Engineering Team. June 1992.

Energy Information Administration (EIA). 2006. Renewable Energy Annual. Accessed June 2008. http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html

Federal Energy Regulatory Commission. 2008. Facility Licensing Data. Accessed June 2008. http://www.ferc.gov/industries/hydropower.asp

Fisher, Bruce. 2008. 2005 Oregon Water Use Compilation. Unpublished provisional data provided by the U.S. Geological Survey and the Oregon Water Science Center. January 2008.

Idaho National Laboratory (INL). 1998. U.S. Hydropower Resource Assessment Final Report (and Oregon Resource Assessment – 2002 update). Accessed June 2008. http://hydropower.inl.gov/resourceassessment/

OCS (Oregon Climate Service). 2008. Map of Oregon's Climate Divisions. Accessed on February 6, 2008 at http://www.ocs.orst.edu/images/zone_map.gif.

OEA (Oregon Office of Economic Analysis). 2008. State and County Population Forecasts and Components of Change, 2000 to 2040. Accessed March, 2008. http://www.oregon.gov/DAS/OEA/demographic.shtml

Oregon Department of Human Services (DHS). 2008. DHS Drinking Water Program Safe Drinking Water Information System. Accessed March, 2008. http://170.104.158.45/

Oregon Water Resources Department (OWRD) 2008. OWRD Water Rights GIS Data. Accessed February, 2008. http://www.wrd.state.or.us/OWRD/MAPS/index.shtml#Water_Right_Data_GIS_Themes

Oregon Water Resources Department (OWRD) 2008. OWRD Hydroelectric Facilities Inventory. Accessed June, 2008. Spreadsheet was provided by Mary Grainey, OWRD.

Oregon Water Resources Department. 2002. Determining Surface Water Availability in Oregon.

Oregon Water Resources Department (OWRD) 1998. Regulated Dam Inventory. Accessed from Oregon GIS spatial clearinghouse. http://www.oregon.gov/DAS/EISPD/GEO/docs/metadata/ordams.htm

Portland State University PRC (Population Research Center). 2007. 2007 Oregon Population Report: Table 4. Population Estimates for Oregon and Its Counties and Incorporated Cities: April 1, 1990 - July 1, 2007.

Sorte, Bruce, and Bruce Weber. 2008. Oregon Agriculture and the Economy. Special Report 1080. Oregon State University Extension Service. February.

U.S. Census Bureau (United States Census Bureau). 2001. Oregon Census Data 2000 TIGER file. U.S. Department of Commerce U.S. Census Bureau Geography Division.

USDA (United States Department of Agriculture). 2004. 2002 Census of Agriculture, Oregon State and County Data, Volume 1, Geographic Area Series, Part 37; County Data Tables 10 (Irrigation) and 23 (Selected Crops Harvested). June 2004.

USGS (United States Geological Survey). 2001. National Land Cover Database Zone 01 Land Cover Layer. http://www.mrlc.gov. 2001.

APPENDIX A

Oregon Climate Zones

Oregon's Climate Divisions

Figure A-1 provides a map of Oregon's climate divisions. **Table A-1** shows the counties that correspond to each climate division.

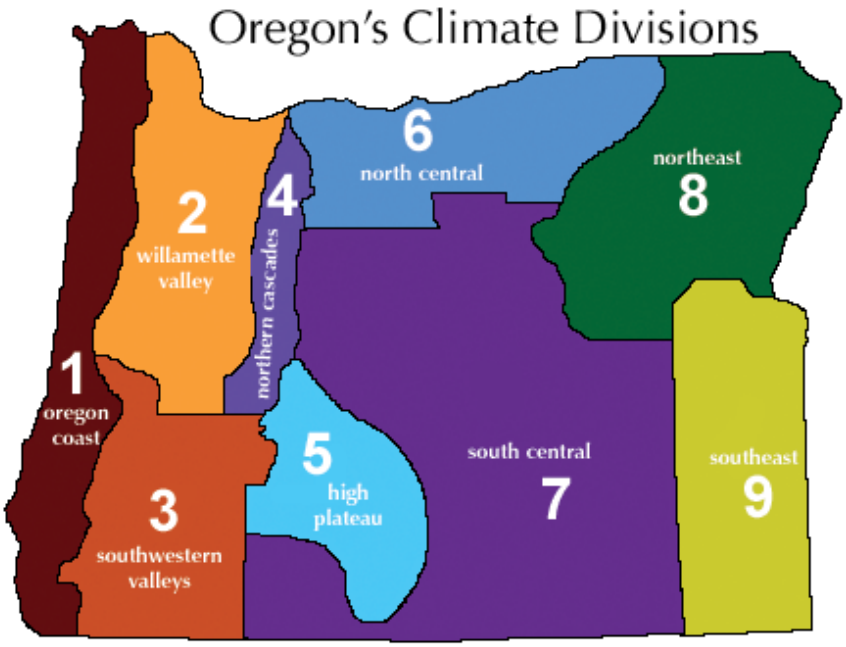


Figure A-1. Oregon's Climate Divisions (OCS 2008)

Table A-1. Oregon Climate Zones (OCS 2008)

Climate Zone	Counties
#1 Oregon Coast	Clatsop, Tillamook, Lincoln, Coos, Curry
#2 Willamette Valley	Columbia, Washington, Multnomah, Yamhill, Clackamas, Lane, Marion, Polk, Benton, Linn
#3 Southwestern Valleys	Jackson, Josephine, Douglas
#4 Northern Cascades	n/a
#5 High Plateau	Klamath
#6 North Central	Hood River, Wasco, Sherman, Gilliam, Morrow, Umatilla
#7 South Central	Deschutes, Jefferson, Wheeler, Crook, Lake, Harney
#8 Northeast	Wallowa, Union, Baker, Grant
#9 Southeast	Malheur

For the municipal and domestic analysis, use of nine climate zones proved overly cumbersome given the large amount of population data used in the calculations. The nine zones defined by OCS were consolidated into five zones as shown in Table A-2.

Table A-2: Climate Zone Consolidation for Municipal Systems and Domestic Wells

Climate Zone - Official	Climate Zone - Used for Project
#1 Oregon Coast	#1 Oregon Coast
#2 Willamette Valley	#2 Willamette Valley
#3 Southwestern Valleys	#3 Southwestern Valleys
#4 Northern Cascades	#4 Northern Cascades
#5 High Plateau	#5 Central
#6 North Central	
#7 South Central	
#8 Northeast	
#9 Southeast	

APPENDIX B

Data Survey and Compilation of Responses

Summary of Survey Respondents

Beginning in March 2008, a survey was distributed to collect data about water demand and water conservation projects in the municipal and agricultural sectors. The first part of the survey was designed to provide water use and demand data for use in developing a water demand forecasting model to assess different future demand scenarios. The second part was an inventory of already-identified, potential conservation projects, including both capital and programmatic projects.

Beginning in early March 2008, the survey was distributed at workshops and other events, to OWRD's database of water users, and by workshop co-sponsors to their member organizations. Through a "Survey Monkey" program, several options were provided to complete the survey online, including the full survey, municipal water use data section only, agricultural water use data section only, or inventory of Conservation Opportunities section only. An April, 2008 letter from the department's Director was distributed to water users, irrigation districts, other key parties encouraging responses to the survey. The tables below summarize the respondents to the survey. OWRD is maintaining the information submitted by the respondents in their database.

Table B-1. Total Survey Responses

Type of Respondent	# of Responses
Municipal Water Supplier	74
Agricultural Use	18
Other ▪ Walla Walla Watershed Council ▪ Powder Basin Water and Stream Committee ▪ Deschutes River Conservancy ▪ Anonymous	4
TOTAL	96

Table B-2. Respondents to Water Demand Forecast Data Request	
Respondent by Geographic Area	Service Area Population
A. Municipal suppliers	
Portland Metro Area	
Portland Water Bureau	545,300
Clackamas River Water Providers	50,175
Sunrise Water Authority	45,000
Oak Lodge Water District	28,000
Boring Water District #24	2,500
Joint Water Commission (City of Beaverton, Clean Water Services, City of Forest Grove, City of Hillsboro, City of Tigard, Tualatin Valley Water District	No data
City of Lake Oswego	No data
South Fork Water Board	80,000
Central/South Willamette Valley	
City of Salem	182,855
City of Corvallis	54,890
City of Woodburn	22,000
City of Junction City	N/A
City of Adair	930 (2000)
City of Monroe	680
Eugene Water & Electric Board	148,595
City of Hubbard	No data
City of Cottage Grove	No data
City of Halsey	No data
City of Scio	720
Springfield Utility Board	56,000
City of Brownsville	No data
Alsea River Water Improvement District	14 to 70+ (seasonal)
Benton County – Alsea County Service District	180
Benton County – Cascade View Service District	122
City of Silverton	9,205 (city) + 200
Buell Red Prairie Water	960
Southwest Oregon	
Medford Water Commission	75,700
Douglas County	No data
Josephine County	No data
Nesika Beach – Ophir Water Dist.	1,140
City of Brookings	6,950
City of Bandon	3,476
Umpqua Basin Water Association	No data
City of Oakland	940
Seal Rock Water District	No data
City of Yachats	No data
Rice Hill Owners Association	No data
City of Port Orford	1,240
Josephine County Rural Planning Commission	No data
City of Myrtle Creek	4,100
City of Coquille	No data

Table B-2. Respondents to Water Demand Forecast Data Request	
Respondent by Geographic Area	Service Area Population
City of Reedsport	No data
Heceta Water District	No data
Northeast Oregon	
City of Pendleton	20,000
City of Halfway	355
City of Baker City	10,035
City of Echo	710
City of Irrigon	No data
City of Nyssa	3,170
City of Ontario	11,741
City of Elgin	No data
Central Oregon	
City of Maupin	490
City of Bend*	No data
Central Oregon Cities Organization	No data
Chenowith Water People's Utility District	No data
River Meadows Improvement District	No data
City of The Dalles	No data
Crescent Water Association	No data
La Pine Water District	No data
City of Sisters	No data
Southeast Oregon	
None	
Northwest Oregon	
City of Astoria	847 services
Falcon Cove Beach Water	15 permanent residences
Oceanside Water District	No data
City of Columbia City	1,955
Netarts Water District	No data
Neahkahnie Water District	1,240
Knappa Water Association	2,200
Westport Water Association	No data
Warren Water Association	2,300
B. Agricultural Users	
Portland Metro Area	
Central/South Willamette Valley	
Lacomb Irrigation District	No data
Queener Irrigation District	No data
Lacomb Irrigation and Hydro	No data
Southwest Oregon	
Medford Irrigation District	No data
Sutherlin Water Control District	No data
Table Rock District Improvement Co.	No data
Northeast Oregon	
West Extension Irrigation District	No data
Harper Southside Irrigation District	No data

Table B-2. Respondents to Water Demand Forecast Data Request	
Respondent by Geographic Area	Service Area Population
Westland Irrigation District	No data
Central Oregon	
Farmers Irrigation District	No data
Middleford Irrigation District	No data
Swalley Irrigation District	No data
North Unit Irrigation District	No data
Farmers Irrigation District	No data
Middle Fork Irrigation District	No data
Central Oregon Irrigation District	No data
Three Sisters Irrigation District	No data
Southeast Oregon	
None	
Northwest Oregon	
Marshland Drainage Improvement Company	No data

OREGON WATER SUPPLY and CONSERVATION INITIATIVE

STATEWIDE WATER DEMAND FORECAST and INVENTORY of POTENTIAL CONSERVATION OPPORTUNITIES SURVEY

The Oregon Water Supply and Conservation Initiative (OWSCI) represents a significant data-gathering effort that will help the State begin to develop a long-term water supply strategy. OWSCI has five components that: (1) assess water demands statewide, (2) identify potential conservation opportunities, (3) inventory potential water storage sites, (4) provide grant funding to communities engaged in long-term water supply planning, and (5) conduct basin-yield analysis. OWSCI is a project of the Oregon Water Resources Department. For more details, visit: www.wrd.state.or.us/OWRD/LAW/owsci.shtml.

This survey focuses on the first two components and is designed to gather information that will help the State develop two web-based tools for county planners and other water supply planners in the community. The first component is a demand forecasting tool that will estimate water demands through 2025 and 2050 at the county or basin level. Users will be able to construct different demand scenarios by modifying assumptions to the model input such as population growth rate, irrigated acreage, and level of conservation. The second component is an inventory that will catalogue potential conservation projects that water users themselves have identified but not yet pursued because of financial, institutional, or other barriers.

As a water provider or user, you know your water demands and water conservation opportunities better than anyone. We would appreciate your assistance with this important data collection effort by completing this survey. Your participation will help provide the building blocks we need to begin to identify our future water demands, our potential future water supplies, and the efforts that will be required to meet those future needs. Please answer the questions as completely as possible, to the best of your ability. We appreciate your help with this important effort.

Please return the completed survey by **March 31, 2008** to the address at the end of the survey. The survey can also be completed online at: www.wrd.state.or.us/OWRD/LAW/owsci.shtml.

ABOUT YOU

PLEASE PRINT CLEARLY

Name: _____ Title: _____

Affiliation: _____

Email or mailing address: _____

Phone: _____

Check the category that applies:

(*This survey is focused on Municipal and Agricultural water users. We will be contacting other types of water users, e.g. industrial, hydropower and self-supplied, later in the process.*)

☐ Municipal Water Supplier ☐ Agricultural Use

☐ Other (please specify) _____

WATER USE DATA FOR DEMAND FORECAST TOOL

OWRD is compiling water use and demand data by major water use categories from existing and readily available reports and directly from water providers through this survey. This data will be used to develop a water demand forecasting model to assess different future demand scenarios. OWRD has access to some of the information requested in this survey through their water use reporting database and from those water providers that have provided water management and conservation plans. However, this survey would provide other additional information not readily available, as well as providing more recent water use data. In addition to the water use data requested, please feel free to submit any current demand forecast data developed by your agency with this survey to help "ground truth" OWRD's demand forecast model results.

Using the tables below, please provide water use data for 2006 and 2007 by type of water use — municipal or agricultural. Please indicate the units used, i.e. mg, gpd, ccf, etc. *If 2006 or 2007 data is not available, please indicate the data years used.*

1. Municipal Water Use

The table below is to be used to provide use data for municipal water uses by water use category. Definitions of the terms are as follows:

Total Production and/or Purchases	The combined production from all your own sources (i.e., diversions and wells), as well as any water you purchase from other utilities.
Wholesaled Water	If applicable, the water you wholesale to other utilities. If you do wholesale water, this water will be subtracted from your "total production and/or purchases" to determine the amount of water you produce and/or purchase for your retail service area.
Single Family Sales	This represents the water you sell to single-family customers. However, since the billing categories vary across water utilities, we realize this may include other residential customers such as duplexes and perhaps even multifamily.
Month	If monthly (or bimonthly) data is not available, please list annual totals instead.

Note: For forecasting purposes, non-residential uses (including industrial/commercial and multi-family) are estimated using the total production, wholesaled water and single-family sales. Information for self-supplied industrial uses will be collected under a separate effort.

Month	2006			2007		
	Total Production &/or Purchases	Wholesaled Water (if applicable)	Single Family Sales	Total Production &/or Purchases	Wholesaled Water (if applicable)	Single Family Sales
	Units: _____	Units: _____	Units: _____	Units: _____	Units: _____	Units: _____
Jan						
Feb						
Mar						
Apr						
May						
Jun						
Jul						
Aug						
Sep						
Oct						
Nov						
Dec						
Total						

1a. Please identify any qualifiers or clarifying information related to the data in the table on the previous page.

_____

_____

_____

1b. Please indicate what kinds of accounts are included in the single-family sales listed above:
☐ Detached ☐ Attached Single Family ☐ Duplex ☐ Triplex ☐ Other (specify) _____

1c. What is the population of your retail service area? _____

1d. How much population growth do you anticipate in your service area in the next 20 years?
☐ less than 5% ☐ less than 10% ☐ 11-50% ☐ 51-100% ☐ >100%

2. Agricultural Water Use

The table below is to obtain use data for agricultural water uses. It should be completed by individual irrigators or, for irrigators within an existing irrigation district, by the irrigation district manager for the entire irrigation district.

Please provide monthly and total yearly numbers for:

1) total irrigated acres
2) type of crop(s) irrigated
3) maximum instantaneous pumping rate in cfs or gpm
4) total volume of water used for each of the last two years in gallons, million gallons, or acre-feet, as outlined in the table below. If monthly amounts are not available, please provide annual totals. For the non-irrigation season, please show as N/A or leave blank.

Month	2006				2007			
	Total Irrigated Acres	Primary Crop(s) Irrigated (indicate %)	Maximum instantaneous pumping rate	Total volume of water used	Total Irrigated Acres	Primary Crop(s) Irrigated (indicate %)	Maximum instantaneous pumping rate	Total volume of water used
	Units: acres	Units: percent	Indicate Units: cfs or gpm	Units: acre-feet	Units: acres	Units: percent	Indicate Units: cfs or gpm	Units: acre-feet
Jan								
Feb								
Mar								
Apr								
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								
Annual Totals	N/A	N/A	N/A		N/A	N/A	N/A	

(Continued)

2a. Please identify any qualifiers or clarifying information related to the data in the table on the previous page.

_____

_____

_____

INVENTORY OF CONSERVATION OPPORTUNITIES

This inventory of already-identified, potential conservation projects includes both capital and programmatic projects. Capital projects are defined as one-time, large investments resulting in water savings. Examples include reclaimed water plants, reservoir covering, transmission line upgrades reducing leaks, or industrial engineering modifications to re-use process water. Programmatic projects are defined as longer term, smaller investments resulting in water savings. Examples include facilitating upgrades to more efficient water using devices (e.g., distributing free showerheads, toilet rebates) and distribution system leak detection programs. The conservation inventory is primarily intended to include "planned" projects rather than projects that are currently being implemented. However, currently active programmatic projects may be listed if they will continue in future years. The inventory of projects submitted will be compiled by county or basin.

Using the table on the following pages, please provide the following information for each planned conservation project (or for projects being implemented in the case of some programmatic programs). Examples are provided below. Please copy the table as needed to provide information on all potential projects.

	Example Capital Conservation Project	**Example Programmatic Conservation Project**
Project Description Provide brief sentence.	Line 3 miles of unlined ditch.	Toilet rebate program for residential customers.
Estimated Future Savings Provide brief sentence, including information regarding savings seasonality.	20 acre feet per year.	If we spend our full budget each year, we estimate 50,000 gallons saved per year.
Seasonality Indicate what part of the year savings are generated (e.g. year-round; summer only; etc.).	Peak (irrigation) season savings.	Savings should occur throughout the year.
Estimated Future Costs Provide brief sentence.	$500,000 total project costs.	$40,000 a year.
Implementation Schedule Provide brief sentence.	Not set. Have conducted cost and savings estimate, but still seeking funding.	We started the program in 2005 and plan to implement until 2015.
Project Funded? Designate either "yes", "no", or provide brief sentence if necessary.	No. Pursuing grant funding.	Yes. In our budget for the next 7 years.

3. Capital Conservation Projects

(Space is provided for up up to 4 projects; please copy in order to submit information on additional projects.)

Project #___/Name	
Project Description	
Estimated Future Savings	
Seasonality	
Estimated Future Costs	
Implementation Schedule	
What are the barriers to implementation, e.g. funding?	
Project #___/Name	
Project Description	
Estimated Future Savings	
Seasonality	
Estimated Future Costs	
Implementation Schedule	
What are the barriers to implementation, e.g. funding?	
Project #___/Name	
Project Description	
Estimated Future Savings	
Seasonality	
Estimated Future Costs	
Implementation Schedule	
What are the barriers to implementation, e.g. funding?	
Project #___/Name	
Project Description	
Estimated Future Savings	
Seasonality	
Estimated Future Costs	
Implementation Schedule	
What are the barriers to implementation, e.g. funding?	

(Continued)

4. Programmatic Conservation Projects

(Space is provided for up up to 4 projects; please copy in order to submit information on additional projects.)

Project #___/Name	
Project Description	
Estimated Future Savings	
Seasonality	
Estimated Future Costs	
Implementation Schedule	
What are the barriers to implementation, e.g. funding?	
Project #___/Name	
Project Description	
Estimated Future Savings	
Seasonality	
Estimated Future Costs	
Implementation Schedule	
What are the barriers to implementation, e.g. funding?	
Project #___/Name	
Project Description	
Estimated Future Savings	
Seasonality	
Estimated Future Costs	
Implementation Schedule	
What are the barriers to implementation, e.g. funding?	
Project #___/Name	
Project Description	
Estimated Future Savings	
Seasonality	
Estimated Future Costs	
Implementation Schedule	
What are the barriers to implementation, e.g. funding?	

OTHER INFORMATION

5. If you have submitted a Water Management and Conservation Plan (WMCP) since 2000, is the conservation information in that WMCP still accurate? ☐ Yes ☐ No

6. Please provide any additional information or comments that you feel may be helpful in preparing the water demand forecast and inventory of conservation opportunities.

(Continued)

WANT TO KNOW MORE?

A series of workshops around the state are being co-sponsored by OWRD and a variety of groups to inform communities of interest about the Oregon Water Supply and Conservation Initiative (OWSCI). Please attend one of these workshops in your area to learn about OWSCI and to participate in the outreach and data collection efforts.

March 4 – Salem, 9:00 am to Noon
725 Summer St, Salem
Oregon Water Resources Dept., Conference Rooms 124 A&B

March 7 – Medford, 9:00 am to Noon
10 S. Oakdale, Medford
Old Jackson County Courthouse, First Floor Meeting Room

March 18 – Central Oregon, 9:00 am to Noon
Redmond Library, 827 SW Deschutes Ave., Redmond

March 19 – Pendleton, 9:00 am to Noon
500 SW Dorion, Pendleton
City of Pendleton Community Room at City Hall

Your assistance in distributing this survey would be greatly appreciated.
Additional surveys and information on these projects and the OWSCI can be obtained by contacting:

Brenda Bateman, Ph.D.
Senior Policy Coordinator
Oregon Water Resources Dept.
725 Summer Street NE, Suite A
Salem, OR 97301
Brenda.O.Bateman@wrd.state.or.us
ph: (503) 986-0879

COGAN
OWENS
COGAN

WHERE TO RETURN THIS SURVEY

Please return the completed survey questionnaire by **March 31, 2008** to:

Cogan Owens Cogan, LLC
813 SW Alder Street, Suite 320
Portland, OR 97205
alisha.dishaw@coganowens.com

HDR

THANK YOU FOR YOUR PARTICIPATION!

APPENDIX C

Data Processing by Water Use Sector

Data Processing – Municipal Systems and Domestic Wells

This section provides more detailed information on how population and per capita water use data were acquired and processed.

Step 1 – Assign characteristics to each block group

1. **County:** Determined by GIS analysis overlaying block group and county boundaries. There are 36 counties in the state. Block groups nest perfectly within counties and therefore a block group can only be associated with one county.

2. **Area Served:** Name of urban area, or identified as "Unincorporated" if rural. Block group is assigned to specific urban area if the majority (i.e. greater than approximately 50%) of the block group is inside the urban boundary. Consequently, block groups that cross the urban boundary, but the majority of which are outside, are considered unincorporated.

3. **Water Administrative Basin:** Determined by GIS analysis overlaying block group and Administrative Basin boundaries. There are 18 basins in the state. Block groups do not nest perfectly within basins and therefore a block group can be associated with more than one basin. However, this occurs in less than 4% of the block groups.

4. **Water Use Class:** Four water use classes were established.

    a. **Full Service – Industrial Skewed (FS-IS):**

    - Represents communities with single family (SF), multifamily (MF), and non-residential water use. Communities in this class have a commercial/industrial component with high water use that may skew the per capita calculation of "total production divided by population."

    - There are six Metropolitan Statistical Areas (MSA) in Oregon. There are 118 cities in those MSAs. The largest 32 of those 118 cities represent approximately 85% of the population of all 118 cities. Block groups entirely within those 32 MSA cities (plus approximately 13 other cities identified as industrial skewed) are given a water use class of FS-IS. Those 10 additional cities were chosen to be categorized as an MSA city because of their similarities, such as size and industrial base, to the other MSA cities. For block groups that straddle the border of those 32+ MSA cities, the block group will be classified as either FS-IS or FS-R (see below). If the majority of the block group population is inside the city (as determined at the census block level), the block group is considered FS-IS. If the majority of the block group population is outside the city, the block group is considered FS-R.

b. **Full Service – Regular (FS-R):**

- Represents communities with SF, MF, and non-residential water use. However, communities in this class do not have a commercial/industrial component with high water use that may skew the per capita water use.

- Block groups entirely within cities other than the 32+ MSA cities are given a water use class of FS-R. For block groups that straddle the border of those cities, the block group will be classified as either FS-R or PR (see below). If the majority of the block group population is inside the city (as determined at the census block level), the block group is considered FS-R. If the majority of the block group population is outside the city, the block group is considered PR.

c. **Primarily Residential (PR):**

- Represents communities that are primarily residential in nature, mostly SF with very little MF or non-residential water use.

- Block groups that contain an entire city or town within their boundaries are given a water use class of PR.

d. **Domestic Well (DW):**

- Represents areas where residences are served by domestic wells.

- Block groups that do not have a city or town in them are given a water use class of DW.

5. **Climate Zone:** Determined by GIS analysis overlaying block group and climate zone boundaries. There are nine official climate zones for the state. For the Municipal Systems and Domestic Wells categories, the modeling team condensed them into five zones, as shown in the table below. Block groups nest perfectly within climate zones and therefore a block group can only be associated with one climate zone.

Climate Zone - OCS	Climate Zone – Consolidated for Analysis
#1 Oregon Coast	#1 Oregon Coast
#2 Willamette Valley	#2 Willamette Valley
#3 Southwestern Valleys	#3 Southwestern Valleys
#4 Northern Cascades	#4 Northern Cascades
#5 High Plateau	#5 Central
#6 North Central	
#7 South Central	
#8 Northeast	
#9 Southeast	

Step 2 - Develop population numbers

1. Began with population by block group from the 2000 Census.

2. Allocated the 2000 block group population between those served by public water systems and those served by domestic wells. This was done by applying the standard ratios defined by the modeling team for each water use class. For example, if a block group was assigned the water use class FS-R, its population was allocated 95% to Municipal Systems and 5% to Domestic Wells.

3. Allocated the 2000 block group population Administrative Basin. About 4% of block groups straddle two basins. This allocation was made based on percent of block group geographic area in each basin.

4. Adjusted the 2000 block group population numbers to 2007, based on growth rates in the PSU report. This was done by calculating the percent change between 2000 and 2007 for each county subarea (either city or unincorporated area) in the PSU report. The 2000 block group population numbers were then multiplied by the appropriate 2000-2007 percent change, based on their assigned "area served" (see Step 2, below). For example, if a block group was assigned to the Corvallis "area served," its 2000 population numbers were multiplied by Corvallis' percent population change from 2000 to 2007.

5. Forecast the 2007 block group population numbers through 2050, based on annual growth rates from the OEA forecasts. The 2007 block group population numbers were multiplied by the appropriate annual growth rate, based on their county. For example, if a block group is in Baker county, its 2007 population numbers were multiplied by the annual growth rate for Baker county estimated by OEA for the years 2005-2010. This same process was repeated for each year, increasing the previous year's population by the appropriate annual growth rate. This results in compounding of growth over time, consistent with OEA's forecast. Note that since the OEA forecasts only go through 2040, the annual growth rates between 2035 and 2040 were used through 2050.

6. Summarized population numbers by county. This was done by first aggregating the 2007 block group population by each county. Then the 2007 county population numbers were multiplied by the appropriate county annual growth rate. For example, the 2007 Jackson county population numbers were multiplied by the annual growth rate for Jackson county estimated by OEA for the years 2005-2010. This same process was repeated for each year, increasing the previous year's population by the appropriate annual growth rate.

7. Summarized population numbers by basin. This was done by first aggregating the 2007 block group population by each basin. Next, weighted average annual growth rates were calculated for each basin. Then the 2007 basin population numbers were multiplied by the appropriate basin weighed average annual growth rate. For example, the 2007 Deschutes basin population numbers were multiplied by the weighted average annual growth rate for Deschutes basin for the years 2005-2010. This same process was repeated for each year, increasing the previous year's population by the appropriate annual growth rate.

Note that there is a slight discrepancy between the total population by block group and by basin. These numbers match 100% in 2007, but they begin to vary in 2010 and the variance increases over time. By 2050, the total population by basin is 99.8% of the total population by block group. The discrepancy occurs more in the domestic wells sector than in the municipal systems sector. For example, by 2050, in the domestic sector, the total population by basin is 96.4% of the total population by block group, while in the municipal sector, the total population by basin is 100.2% of the total population by block group. The primary reason for the discrepancy is associated with the weighted average growth rate needed since the boundaries for block groups and basins do not align perfectly. Despite the discrepancy, the numbers were deemed acceptable for policy-level analysis.

Step 3 – Subdivide population into Municipal System and Domestic Well categories

This provides an estimate of what percent of the demand is supplied by Municipal Systems vs. Domestic Wells. This is based on the Water Use Class defined. These assumptions were checked by comparing the resulting population served by public water systems by similar estimates by the Oregon Department of Human Services. The estimates by both sources were within 3% of each other.

Step 4 - Develop representative per capita demands

1. Within each climate zone, select three representative public water systems (from the returned surveys) for each of the three water use classes not including domestic wells.

    a. **Full Service – Industrial Skewed (FS-IS):** There are six Metropolitan Statistical Areas (MSA) in OR. There are 118 cities in those MSAs. The largest 32 of those 118 cities represent approx 85% of the population of all 118 cities. An additional 13 cities, which are not located in an MSA county, are added to these 32 cities. Select surveys from three utilities from these 45 cities.

    b. **Full Service – Regular (FS-R):** See directly above. Select surveys from the three representative utilities of the remaining non-MSA cities that have two or more census block groups crossing their boundaries that are classified as FS-R (Step 1, item 4b).

    c. **Primarily Residential (PR):** Block groups that are not populated enough to be considered FS-R, or those that are entirely within a single block group are given a PR designation (Step 1, item 4c). Select three utilities from block groups that are entirely within a single block group.

2. Within each climate zone, calculate the per capita demand for each water use class, using data from the returned surveys:

    a. **Full Service – Industrial Skewed (FS-IS):** (Production) / (population served).

    b. **Full Service – Regular (FS-R):** (Production) / (population served).

    c. **Primarily Residential (PR):** (SF sales) / (population served).

d. **Domestic Well (DW):** Use the PR per capita demand.

3. Assign per capita demands to each block group. This is done according to the water use class and climate zone assigned to each block group. For example, a block group with the water use class of Full Service – Regular (FS-R) and the climate zone of Central will be assigned the per capita demand calculated by the representative FS-R public water systems in the Central climate zone. **Figure C-1** shows the water use class designation for each block group.

4. Calculate a weighted average per capita demand for each county. Since the demand forecast is presented at the county level, it is necessary to develop a per capita demand number representing each county. This is accomplished by calculating a weighted average per capita demand for each county. Table C-1 summarizes the weighted average per capita demand for each county used in the reference forecast.

5. Calculate a weighted average per capita demand for each basin. Since the demand forecast is presented at the basin level, it is necessary to develop a per capita demand number representing each basin. This is accomplished by calculating a weighted average per capita demand for each basin.

Step 5 - Calculate the baseline forecast

1. The baseline demand forecast is calculated as follows:

   a. **By County for Municipal Systems:** For each county, the population served by public water systems is multiplied by the county weighted average per capita demand.

   b. **By County for Domestic Wells:** For each county, the population served by domestic wells is multiplied by the county weighted average per capita demand.

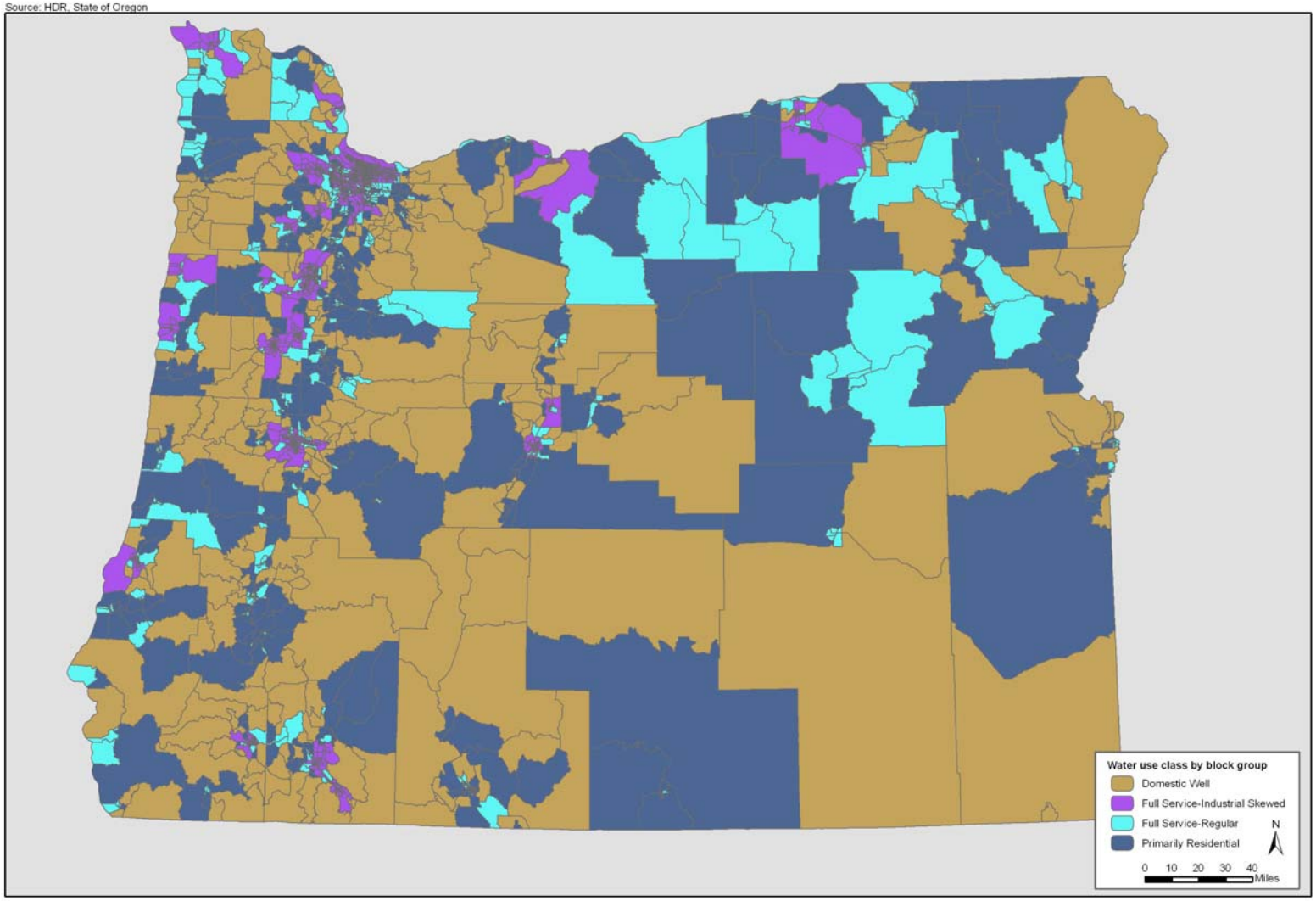
   c. **By Basin for Municipal Systems**: For each basin, the population served by public water systems is multiplied by the basin weighted average per capita demand.

   d. **By Basin for Domestic Wells:** For each basin, the population served by domestic wells is multiplied by the basin weighted average per capita demand.

Table C-1. Summary of Weighted Average Monthly Per Capita Demand by County												
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Baker	73	87	87	158	344	478	558	566	357	152	75	72
Benton	99	101	99	107	129	161	187	181	153	105	102	101
Clackamas	84	87	85	93	120	151	175	170	139	93	87	85
Clatsop	99	99	104	107	139	159	190	188	155	116	106	100
Columbia	85	87	84	93	119	152	177	172	141	94	87	85
Coos	94	95	99	103	135	156	183	181	148	109	100	95
Crook	67	88	87	163	361	509	582	610	381	165	74	71
Curry	81	83	90	92	133	147	171	170	134	103	89	80
Deschutes	81	105	84	131	259	394	436	547	378	235	111	99
Douglas	84	88	96	98	137	150	168	160	132	105	93	84
Gilliam	92	85	89	140	296	387	488	435	286	113	77	76
Grant	77	86	88	154	334	459	544	538	342	144	75	73
Harney	75	87	88	156	339	468	551	551	349	148	75	73
Hood River	68	87	87	162	356	501	576	599	375	162	74	71
Jackson	127	122	71	161	328	311	321	284	237	140	137	123
Jefferson	59	88	86	171	380	546	610	663	409	181	72	69
Josephine	120	117	72	154	308	292	297	257	216	131	129	116
Klamath	62	88	86	168	374	533	601	645	400	175	73	70
Lake	62	88	86	168	373	531	599	642	398	175	73	70
Lane	92	94	92	100	124	156	183	178	148	100	95	94
Lincoln	94	96	98	103	133	156	183	179	148	107	99	95
Linn	84	87	84	92	119	152	177	172	141	94	87	85
Malheur	70	87	87	161	353	495	571	590	370	159	74	71
Marion	91	93	90	98	122	156	183	178	148	99	94	92
Morrow	72	87	87	159	348	485	564	576	363	155	74	72
Multnomah	108	109	107	115	134	166	196	190	163	112	111	112
Polk	98	100	97	106	128	160	186	181	152	104	100	100
Sherman	48	90	85	182	411	603	655	746	454	205	71	67
Tillamook	76	80	85	89	130	145	165	164	128	97	83	75
Umatilla	87	103	85	127	246	366	417	502	352	218	110	99
Union	79	86	88	152	329	449	536	524	334	140	75	73
Wallowa	74	87	87	157	342	474	555	559	353	150	75	72
Wasco	90	108	84	119	221	341	382	494	357	240	120	107
Washington	94	96	93	101	125	157	184	179	149	101	96	95
Wheeler	48	90	85	182	411	603	655	746	454	205	71	67
Yamhill	89	92	89	98	123	154	179	174	144	97	92	90

Figure C-1 Water Use Class Designation for Census Block Groups

Source: HDR, State of Oregon



Water Use Class by Census Block Group
FIGURE C-1

HDR
ONE COMPANY | *Many Solutions*

This page intentionally left blank.

Data Processing - Irrigated Agriculture

Some processing of the raw data was necessary to conduct the analysis in a standardized manner across the state. Key processing steps and assumptions used in this analysis are described below.

Crop Groups

Three variables for the water use analysis were obtained from the USGS compilation, including: irrigated acres, estimated crop water requirements, and estimated irrigation efficiency. Data for 37 crops and all counties were utilized in the analysis. These data were grouped into 14 crop groups based on the typical consumptive use of each crop and based on relationships expected for developing alternative scenarios. Stock water was included as an additional crop group, although USGS only reported the total demand by county; one acre-foot per acre was assumed for stock water demand. The crop groups included in the analysis are listed in table below.

Crop Groups for Agricultural Sector

Group Name	Crops Included in Group (Fisher 2008)
Alfalfa & Other Hay	Alfalfa, Hay
Berries	Blueberries, Cranberries, Strawberries, Vineberries
Corn	Corn Grain, Corn Silage, Sweet Corn, Silage
Grapes	Grapes
Grass Seed	Grass Seed
Horticulture	Bulbs, Mint & Oils, Miscellaneous Crops, Nursery
Legumes	Beans, Peas
Miscellaneous	Hops, Confidential Crops
Pasture	Pasture
Root Crops	Potatoes, Sugar Beets
Small Grains	Barley, Oats & Rye
Tree Fruits & Nuts	Apples, Cherries, Hazelnuts, Peaches, Pears, Prunes & Plums
Vegetables	Melons & Squash, Onion & Garlic, Seed Crops, Tomatoes
Wheat	Wheat
Livestock	Stock water

Water Use Calculations

The following steps were used to calculate the baseline water demand for irrigation, at the county level:

1. Estimate acreage used for growing each irrigated crop group, county by county throughout the state.
2. Multiply acres of each crop group by the county-specific, average irrigation requirement for that crop group. This provides estimated consumptive use for each crop group in each county.
3. Divide consumptive use by estimated irrigation efficiency and estimated conveyance efficiency (these are fractional values, so division <u>increases</u> the quantity of water).

This provides an estimate of total water diverted or pumped, by crop group for each county.

Expressed as an equation, this procedure is:

$$D_c = [(A \times I) \div E_i] \div E_c$$

Where:

D_c represents total demand for the crop group

A = irrigated acreage in that crop group

I = irrigation requirement for that crop group, expressed in inches or acre-feet

E_i = irrigation efficiency for that crop group (the fraction of water applied to a field that is actually consumed by the crop. This fraction depends in part on the irrigation technology used.)

E_c = conveyance efficiency for that crop group (the fraction of water diverted or pumped that actually reaches the field. This fraction depends on the type and condition of conveyance facilities and the distance from the water source to the field).

The total agricultural water use in each county is estimated by summing water use for all of the crop groups grown in that county.

Monthly Irrigation Patterns and Climate Zones

Monthly irrigation timing was incorporated into the analysis in order to develop demand estimates by month. Monthly irrigation patterns were developed by applying the average (5 in 10 years) monthly distribution of irrigation requirements from the *Oregon Crop Water Use and Irrigation Requirements* (Cuenca, et al. 1992) to the estimated total water use for each crop group in each county. In some cases, irrigation requirements for some crop groups in some counties were not reported; a general pattern was developed as a general, "place holder" for these crop groups, based on patterns of other crops reported in that county.

Geography

The National Land Cover Database (NLCD) was used to allocate irrigated acres from county-level data to develop estimates of irrigated acres and water demand for each Water Administrative Basin. The NLCD was used to geographically associate each county's irrigated acreage with a Water Administrative Basin, then reallocate the crop groups and associated demands to each Basin. The NLCD uses spatial imaging to categorize types of land cover such as pasture, cultivated crops, forest, and developed land. A map of these land cover types are shown in **Figure C-2**. A Geographic Information System (GIS) was used to identify areas in each county that were categorized as pasture or cultivated crops in the NLCD, and then assign these areas to Water Administrative Basins. The crop group data for each county was then used to calculate percentages of each crop group found in each Water

Administrative basin, based on the percentage of each county's acreage associated with each crop group.

Forecasting Change in Irrigated Acreage

There is currently no comprehensive or definitive data or position regarding trends in irrigated agriculture – especially quantitative estimates. Part of the reason is there are significant complexities in forecasting agricultural trends because of the many factors and the "elasticity" in those factors. However, for the purposes of this study, a cursory methodology was used by the modeling team to develop estimates for change in irrigated acreage.

A change in total irrigate acreage was defined for each county (percent change in 5-year increments) from the 2005 values using the following factors. The percent change is considered a "best guess" using a reasoned but admittedly subjective approach by the modeling team. It should be kept in mind that these values produce a demand for the agricultural category that is a single potential outcome – and is considered a "reference forecast" to which users of the forecasting tool can compare other scenarios.

1. Trend in acreage change from '97-'02, '02-'05, and '97-'05 using data from USDA Census of Agriculture.
2. The relative amount of "prime farmland" in the county based on NRCS STATSGO data. A qualitative rating of 0-2 was assigned to each county; with 2 meaning high acreage of prime farmland; a score of 2 tends to support increasing trend in acreage.
3. The population growth rate the modeling team assigned to the county over the 40 year planning period was used as an indicator of potential for converting agricultural land to non-agricultural land (i.e. development). A qualitative rating of 0-2 was assigned to this "land conversion potential" factor with 2 meaning high potential for land conversion from agricultural to non-agricultural; a score of 2 tends to reduce any potential increasing trend in acreage.
4. The modeling team assumed that "water availability" is not a critical factor for demand for irrigated acreage; the question then becomes: if water were available, would there be a likely increase in irrigated acreage because of the types of crops grown, the type of land present (i.e. prime farmland), and the emphasis on agricultural in the particular county?
5. The modeling team assumed that generally commodity prices will remain positive (high) and so the tendency is for farmers to look to increase their acreage for those types of crops. It was also assumed that generally the demand for local foods will continue to increase in the state so that counties that grow "food crops" will also tend to increase their acreage.

Factors considered in developing the change in irrigated acreage included input from staff at Oregon Department of Agriculture.

On average, this analysis results in biasing the irrigated agricultural demand to increase across the state. Table C-2 summarizes the data and analysis used to assign the change in irrigated acreage for each county. The percentages shown in the "Total Acreage Change"

column is the approximate total percentage increase from 2010 to 2050. A value (%) was derived for the 5-year increment percent change used in the base data for the forecasting tool. The percentage is applied to every crop group. This assumes the counties that tend to grow hay/pasture/wheat will continue (primarily) and that counties that do vegetable/food crops will also continue to do so.

Table C-2. Data and Analysis for Change in Irrigated Acreage

	1997 Acreage (acres)	2002 Acreage (acres)	2005 Acreage (acres)	% Change '97-'02	% Change '02-'05	% Change '97-'05	Prime Farmland Rating	Population Growth Rate	Municipal Population Served	Urban potential Rating	5-year % change	~Total Acreage Change (to 2050)	~Final Acreage (acres)	Comments - assuming water availability is not a limit; climate change is not an issue; conservation and irrigation practices continue as present; trend in types of crops grown generally continues with some exceptions
Baker	135,730	127,077	146,990	-6.4%	15.7%	8.3%	2	1.53%	13,105	0	3.13%	32%	194,027	increasing trend in the past 10 years; significant prime farmland; significant commodity crops - assumes high commodity prices; increase in food crops; limited to no land conversion;
Benton	20,743	20,655	14,463	-0.4%	-30.0%	-30.3%	2	4.58%	79,648	2	0.00%	0%	14,463	high decreasing trend in past 10 years; moderate land conversion potential; primarily food crops - assumes increase in local food demand reduces maintains current acreage:
Clackamas	24,877	26,927	28,276	8.2%	5.0%	13.7%	2	13.69%	323,579	2	0.44%	4%	29,407	moderate increasing trend in past 10 years; primarily horticulture and food crops - assumes increasing demand for local foods continues increasing trend; high land conversion potential limits and essentially neutralizes increasing trend;
Clatsop	510	842	1,354	65.1%	60.8%	165.5%	0	1.78%	30,631	0	3.13%	32%	1,787	high increasing trend in past 10 years; very limited agricultural activity; mostly corn and pasture; assumes increasing trend in food crop demands; very limited land conversion potential; but no prime farmland will limit expansion of irrigated ag;
Columbia	1,477	2,818	3,692	90.8%	31.0%	150.0%	1	8.51%	38,492	1	3.13%	32%	4,874	high increasing trend in past 10 years; very limited agricultural activity; mostly food crops and pasture; assumes increasing trend in food crop demands; has prime farmland; but some land conversion potential will limit expansion of irrigated ag;
Coos	11,083	10,848	5,833	-2.1%	-46.2%	-47.4%	0	0.49%	52,294	0	-0.92%	-8%	5,366	high decreasing trend in past 10 years; high land conversion potential; mostly corn, pasture and berries; assumes increase in food crop demand; no prime farmland; decreasing trend will continue; but be limited assuming increase in food crop demand and most of the land has already been removed from ag use;
Crook	70,359	77,861	74,422	10.7%	-4.4%	5.8%	1	15.34%	19,491	2	0.44%	4%	77,399	low to moderate increasing trend in past 10 years; mostly pasture and commodity crops with some food crops; assumes high commodity prices will continue increasing trend; but high land conversion potential will limit increasing trend;
Curry	3,463	2,804	3,445	-19.0%	22.9%	-0.5%	0	2.31%	15,346	0	0.22%	2%	3,514	limited change in past 10 years; mostly pasture and berries; assumes increasing food crop demand will increase acreage; limited land conversion potential; but no prime farmland limits growth trend;
Deschutes	42,919	44,436	48,899	3.5%	10.0%	13.9%	1	14.24%	129,742	2	0.86%	8%	52,811	moderate increasing trend in past 10 years; primarily hay and pasture; assuming commodity prices are good and food crop demand increases; high quantity of prime farmland; but high land conversion potential limits increasing trend;
Douglas	17,450	15,602	14,167	-10.6%	-9.2%	-18.8%	1	7.95%	76,047	1	0.86%	8%	15,301	moderately high decreasing trend in past 10 years; primarily pasture, hay corn and food crops; assumes commodity prices will be good; demand for food crops increase; and presence of prime farmland will reverse decreasing trend; but moderate potential for land conversion will limit increasing trend slightly:

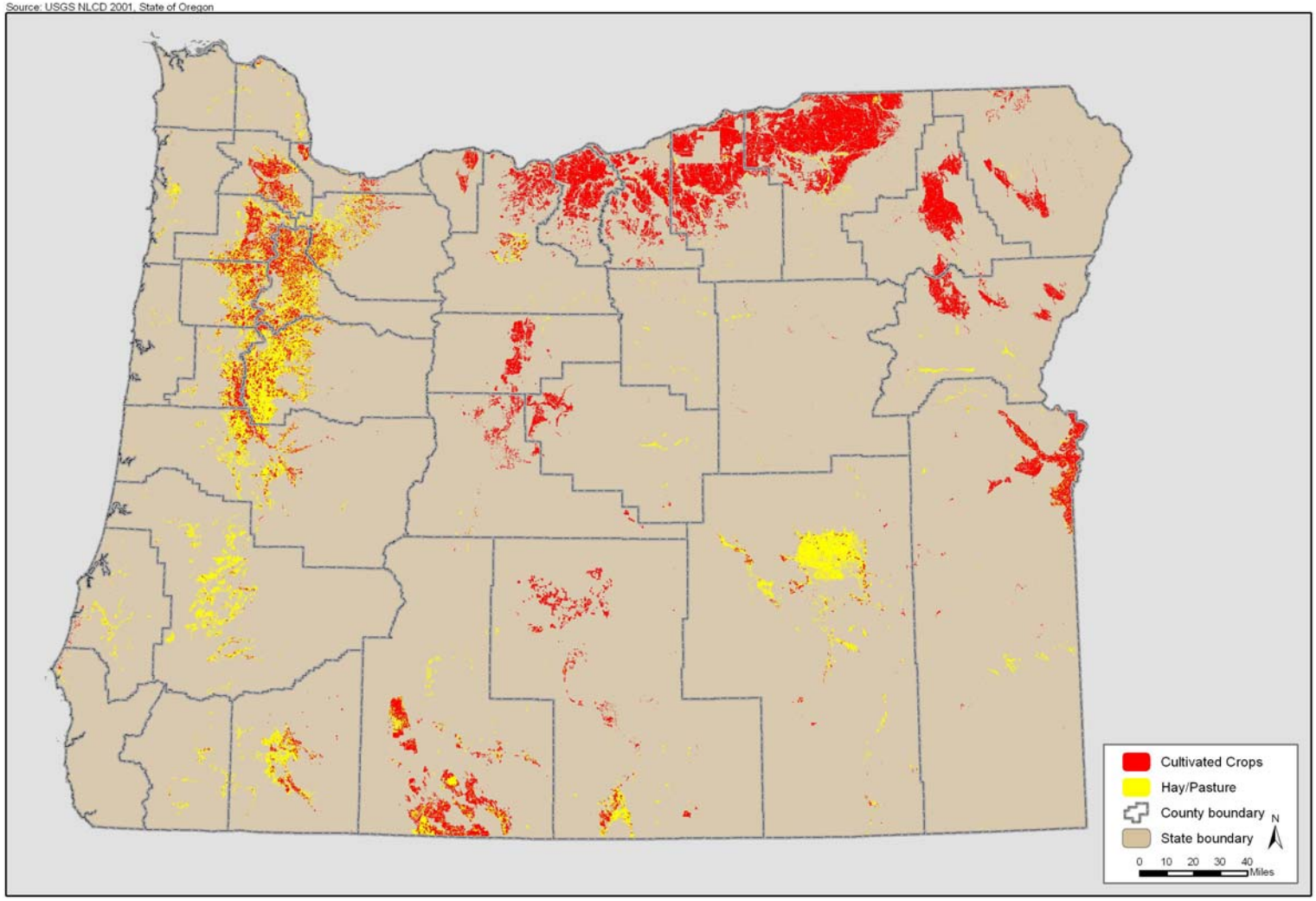
	1997 Acreage (acres)	2002 Acreage (acres)	2005 Acreage (acres)	% Change '97-'02	% Change '02-'05	% Change '97-'05	Prime Farmland Rating	Population Growth Rate	Municipal Population Served	Urban potential Rating	5-year % change	~Total Acreage Change (to 2050)	~Final Acreage (acres)	Comments - assuming water availability is not a limit; climate change is not an issue; conservation and irrigation practices continue as present; trend in types of crops grown generally continues with some exceptions
Gilliam	4,046	6,830	5,319	68.8%	-22.1%	31.5%	2	6.66%	1,436	1	2.42%	24%	6,596	high increasing trend in past 10 years; primarily hay, pasture and food crops; assumes commodity prices good and demand for local food increases will continue increasing trend; a lot of prime farmland; but moderate land conversion potential will limit increasing trend somewhat;
Grant	47,839	41,854	56,713	-12.5%	35.5%	18.5%	1	0.43%	5,899	0	2.42%	24%	70,324	high increasing trend in past 10 years; primarily hay and pastures; assumes commodity prices are good; no land conversion potential; some prime farmland;
Harney	144,512	133,008	171,334	-8.0%	28.8%	18.6%	2	7.70%	5,380	1	2.42%	24%	212,454	high increasing trend in past 10 years; primarily hay and pastures; assumes commodity prices are good; some land conversion potential; significant prime farmland;
Hood River	19,848	19,596	18,093	-1.3%	-7.7%	-8.8%	1	11.81%	15,349	1	-0.45%	-4%	17,369	moderate decreasing trend in past 10 years; primarily fruits and nuts, some hay/pasture; assumes competition in fruit market; good commodity prices; high land conversion potential will continue decreasing trend;
Jackson	53,843	49,887	50,127	-7.3%	0.5%	-6.9%	2	10.60%	180,368	2	0.00%	0%	50,127	moderate decreasing trend in past 10 years; primarily hay/pasture with some fruits; high land conversion potential, but assumes good commodity prices and prime farmland will neutralize development;
Jefferson	54,134	56,954	47,712	5.2%	-16.2%	-11.9%	2	14.44%	12,755	2	0.00%	0%	47,712	moderate decreasing trend in past 10 years; primarily hay/pasture and grass; high land conversion potential will continue decreasing trend; but good commodity prices and presence of prime farmland will essentially neutralize decreasing trend;
Josephine	12,256	9,415	13,131	-23.2%	39.5%	7.1%	2	9.78%	67,067	2	0.22%	2%	13,394	moderate increasing trend in past 10 years; primarily hay/pasture with some fruits; assumes good commodity prices and prime farmland will continue increasing trend; but moderate to high land conversion potential will limit increasing trend;
Klamath	242,482	242,153	195,203	-0.1%	-19.4%	-19.5%	1	5.51%	44,915	1	-0.45%	-4%	187,395	high decreasing trend in past 10 years; primarily commodity crops; some prime farmland; moderate land conversion potential; discussions of removing dams (ESA) will continue decreasing trends; but assumes good commodity prices will limit decreasing trend;
Lake	204,567	194,320	192,849	-5.0%	-0.8%	-5.7%	2	0.74%	5,125	0	0.86%	8%	208,277	moderate to low decreasing trend in past 10 years; primarily commodity crops; assumes good commodity prices will reverse decreasing trend; significant prime farmland; no land conversion potential;
Lane	24,155	22,001	18,960	-8.9%	-13.8%	-21.5%	2	8.68%	308,761	2	-0.22%	-2%	18,581	high decreasing trend in past 10 years; primarily food crops; assumes demand for local foods increases; lots of prime farmland will limit decreasing trend; but moderate to high land conversion potential;
Lincoln	542	1,361	757	151.1%	-44.4%	39.6%	0	5.99%	37,862	1	0.86%	8%	817	high increasing trend in past 10 years, primarily hay/pasture; assumes good commodity prices; local food demand increases; no prime farmland and moderate land conversion potential limits growth;

	1997 Acreage (acres)	2002 Acreage (acres)	2005 Acreage (acres)	% Change '97-'02	% Change '02-'05	% Change '97-'05	Prime Farmland Rating	Population Growth Rate	Municipal Population Served	Urban potential Rating	5-year % change	~Total Acreage Change (to 2050)	~Final Acreage (acres)	Comments - assuming water availability is not a limit; climate change is not an issue; conservation and irrigation practices continue as present; trend in types of crops grown generally continues with some exceptions
Linn	32,671	30,503	29,419	-6.6%	-3.6%	-10.0%	2	8.55%	96,643	2	0.22%	2%	30,007	moderate decreasing trend in past 10 years; primarily hay/pasture and food crops; good commodity prices and demand for local food balances out the high prime farmland and land conversion potential;
Malheur	242,797	223,263	214,639	-8.0%	-3.9%	-11.6%	2	8.13%	20,368	1	1.27%	12%	240,396	moderate decreasing trend in past 10 years; primarily commodity crops; assumes good commodity prices; presence of prime farmland results increasing trend; but moderate land conversion potential will temper growth;
Marion	95,368	100,415	93,515	5.3%	-6.9%	-1.9%	2	9.57%	289,505	2	0.00%	0%	93,515	low decreasing trend in past 10 years; primarily food crops and some pasture; assumes good commodity prices and demand for local foods; lots of prime farmland; but land conversion potential will balance out any increases;
Morrow	97,394	94,798	99,468	-2.7%	4.9%	2.1%	2	15.82%	10,741	1	2.42%	24%	123,341	low increasing trend in past 10 years; primarily commodity and food crops; assumes good commodity prices and local food demand; prime farmland, moderate land conversion potential tempers growth somewhat;
Multnomah	7,636	7,780	7,139	1.9%	-8.2%	-6.5%	2	5.04%	705,213	1	-0.45%	-4%	6,853	low decreasing trend in past 10 years; primarily food crops and some pasture; assumes good commodity prices and demand for local foods; lots of prime farmland; but high land conversion potential will balance out any increases;
Polk	14,102	12,984	21,132	-7.9%	62.8%	49.9%	2	17.34%	65,531	2	1.27%	12%	23,668	high increasing trend in past 10 years; primarily food crops and some pasture; assumes good commodity prices and demand for local foods; lots of prime farmland; but land conversion potential will balance some increase;
Sherman	1,810	1,949	9,636	7.7%	394.4%	432.4%	1	3.41%	1,176	0	3.13%	32%	12,720	high increasing trend in past 10 years; primarily hay, pasture; assumes commodity prices good and demand for local food increases will continue increasing trend; a lot of prime farmland; and low land conversion potential;
Tillamook	5,988	6,066	8,834	1.3%	45.6%	47.5%	0	5.47%	14,783	1	0.86%	8%	9,540	high increasing trend in past 10 years; mostly pasture and livestock; assumes increasing trend in food crop demands; has no prime farmland; but some land conversion potential will limit expansion of irrigated ag;
Umatilla	130,334	121,909	123,345	-6.5%	1.2%	-5.4%	2	9.89%	61,579	1	2.42%	24%	152,948	low increasing trend in past 10 years; primarily commodity and food crops; assumes good commodity prices and local food demand; prime farmland, moderate land conversion potential tempers growth somewhat;
Union	64,346	64,901	51,088	0.9%	-21.3%	-20.6%	2	6.51%	22,535	1	1.27%	12%	57,218	decreasing trend in the past 10 years; significant prime farmland; significant commodity crops and food crops - assumes high commodity prices; increase in food crops; limited to no land conversion;
Wallowa	49,070	40,323	50,257	-17.8%	24.6%	2.4%	2	5.76%	5,565	1	1.66%	16%	58,298	slight increasing trend in the past 10 years; significant prime farmland; significant commodity crops - assumes high commodity prices; increase in food crops; limited to no land conversion;

	1997 Acreage (acres)	2002 Acreage (acres)	2005 Acreage (acres)	% Change '97-'02	% Change '02-'05	% Change '97-'05	Prime Farmland Rating	Population Growth Rate	Municipal Population Served	Urban potential Rating	5-year % change	~Total Acreage Change (to 2050)	~Final Acreage (acres)	Comments - assuming water availability is not a limit; climate change is not an issue; conservation and irrigation practices continue as present; trend in types of crops grown generally continues with some exceptions
Wasco	26,910	31,874	20,583	18.4%	-35.4%	-23.5%	2	5.64%	22,159	1	0.86%	8%	22,230	decreasing trend in past 10 years; primarily hay/pasture, fruits and nuts; assumes competition in fruit market; good commodity prices; some land conversion potential; but high prime farmland;
Washington	27,163	25,182	25,987	-7.3%	3.2%	-4.3%	2	15.64%	478,398	2	-0.45%	-4%	24,948	low decreasing trend in past 10 years; primarily food crops and some pasture; assumes good commodity prices and demand for local foods; lots of prime farmland; but high land conversion potential will balance out any increases;
Wheeler	9,030	13,524	6,711	49.8%	-50.4%	-25.7%	0	1.58%	1,163	0	-0.22%	-2%	6,577	high decreasing trend in past 10 years; low land conversion potential; mostly commodity crops; assumes increase in food crop demand; no prime farmland; decreasing trend will continue; but be limited assuming increase in food crop demand and most of the land has already been removed from ag use; -.25%
Yamhill	22,024	24,907	25,199	13.1%	1.2%	14.4%	2	15.62%	84,162	2	0.86%	8%	27,215	increasing trend in past 10 years; primarily food crops and some pasture; assumes good commodity prices and demand for local foods; lots of prime farmland; but land conversion potential will balance some of the increase;

Figure C-2: NLCD Land Cover Distribution used to Distribute Crop Groups

Source: USGS NLCD 2001, State of Oregon



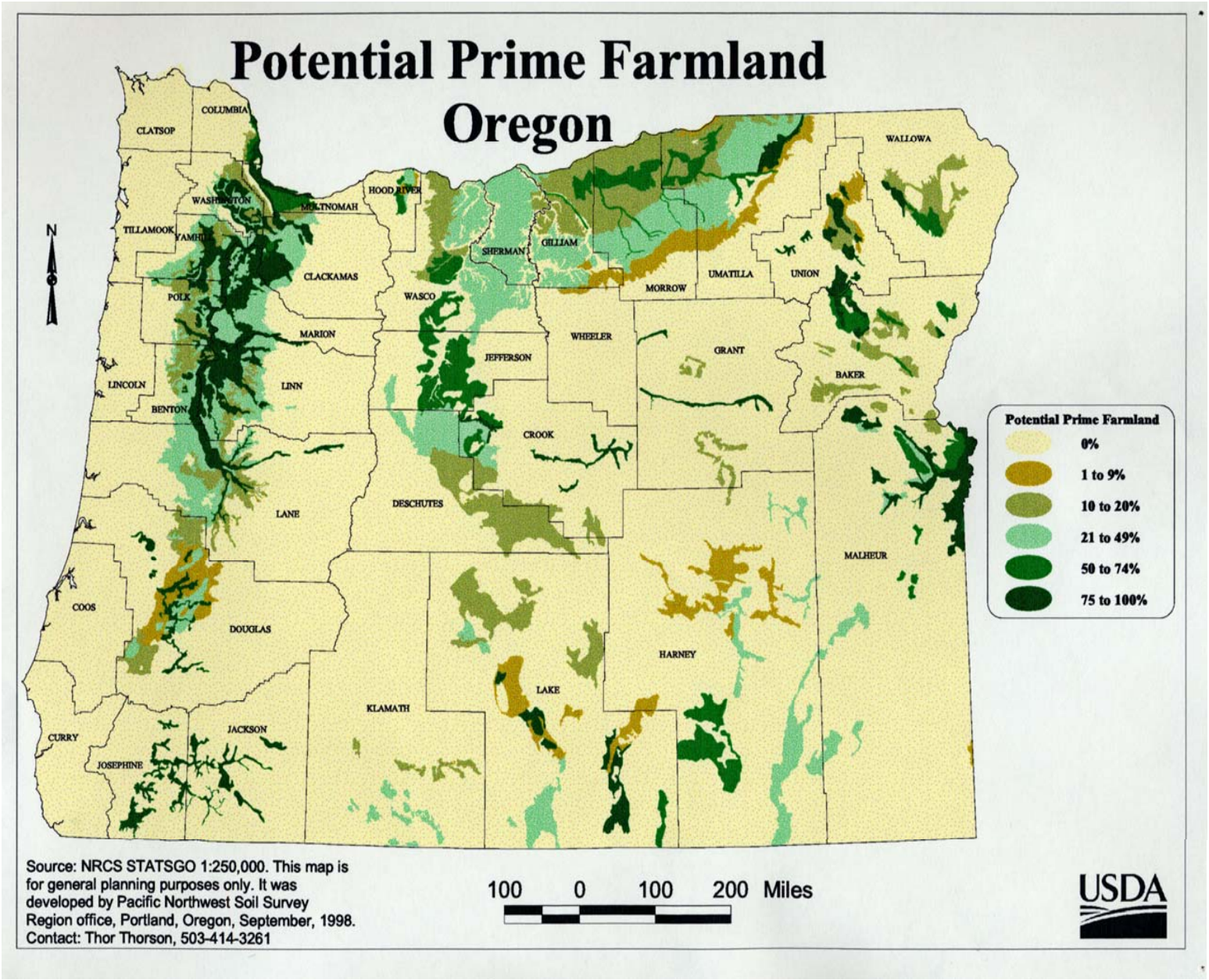
Agricultural Land distribution per National Land Cover Dataset 2001

FIGURE C-2

HDR ONE COMPANY | Many Solutions

This page intentionally left blank.

Figure C-3: Potential Prime Farmland (PDF from NRCS STATSGO, 1998)



This page intentionally left blank.

APPENDIX D

Sample Output from Forecasting Tool

Screen Capture of Main Menu

STATE/REGIONAL WATER DEMAND MODEL
OREGON WATER RESOURCES DEPARTMENT

Version 10
(Updated on July 8, 2008)

TABLE OF CONTENTS

List of Worksheets	Worksheet Description			
Instructions	This worksheets provides details on how to operate this workbook.			
Main Menu	This worksheet provides a hyperlinked listing of each of the worksheets within this workbook, including descriptions of each worksheet.			
Final Outputs				
Summary Results	Graphs and tables displaying demands for the Base and Override scenarios. User is capable of selecting geographic area, area name, month(s) or year, units, and type of chart to display.			
Agricultural Results	Graphs and tables displaying Agricultural demands for the Base and Override scenarios. User is capable of selecting geographic area, area name, month(s) or year, and units.			
Results by Year	Graphs and tables displaying demands by month for a selected year for the Base and Override scenarios. User is capable of selecting geographic area, area name, year, and units.			
Database Tables for the Base Scenario				
Color Coding for Cells on Base Sheets	White or Grey Highlighting: Cells Containing Formulas	Green Highlighting: Cells with Values Generated by Visual Basic	Yellow Highlighting: Cells Accepting User Input on Override Sheets	
Base - Municipal Systems	This worksheet provides the population, per capita water use, and demands related to water provided by municipal water systems. Data is provided for Statewide, County and Administrative Basins on a monthly basis for 2007 and five year increments starting in 2010 through 2050.			
Base - Domestic Wells	This worksheet provides the population, per capita water use, and demands related to water provided by domestic wells. Data is provided for Statewide, County and Administrative Basins on a monthly basis for 2007 and five year increments starting in 2010 through 2050.			
Base - Industrial	This worksheet provides the Industrial demand data. Data is provided for Statewide, County and Administrative Basins on a monthly basis for 2007 and five year increments starting in 2010 through 2050.			
Base - Agricultural	This worksheets provides the Agricultural demand data by Crop Group. Data is provided for Statewide, County and Administrative Basins on a monthly basis for 2007 and five year increments starting in 2010 through 2050. Skip Update Check Box: Allows user to turn off the automated calculation of cells calculated by Visual Basic (i.e. green cells). All cells are recalculated after each input cell is modified, unless check box is checked. When the user turns off Skip Update (i.e. unchecks box) the calculations are run. Agriculture only.			
Base - Agricultural Distribution	This worksheets contains two tables identifying the allocation of water demand by crop by county to each Administrative Basin. Skip Update Check Box: Allows user to turn off the automated calculation of cells calculated by Visual Basic (i.e. green cells). All cells are recalculated after each input cell is modified, unless check box is checked. When the user turns off Skip Update (i.e. unchecks box) the calculations are run. Agriculture only.			
Database Tables for User Input (Manual Overrides)				
Color Coding for Cells on Override Sheets	White or Grey Highlighting: Cells Containing Formulas	Green Highlighting: Cells with Values Generated by Visual Basic	Yellow Highlighting: Cells Accepting User Input (Default = Base Inputs)	Pink Highlighting: Cells Modified by the User
Override - Municipal Systems	This worksheet provides the user the ability to modify select variables for the municipal sector. Data is provided for Statewide, County and Administrative Basins on a monthly basis for 2007 and five year increments starting in 2010 through 2050. Reset Button: Provides the user an automated method to reset modified inputs to their original values. Pop-up form provides the user the ability to reset only selected cells or the entire worksheet.			
Override - Domestic Wells	This worksheet provides the user the ability to modify select variables for domestic wells sector. Data is provided for Statewide, County and Administrative Basins on a monthly basis for 2007 and five year increments starting in 2010 through 2050. Reset Button: Provides the user an automated method to reset modified inputs to their original values. Pop-up form provides the user the ability to reset only selected cells or the entire worksheet.			
Override - Industrial	This worksheet provides the user the ability to modify select inputs to calculated Industrial demand. Data is provided for Statewide, County and Administrative Basins on a monthly basis for 2007 and five year increments starting in 2010 through 2050. Reset Button: Provides the user an automated method to reset modified inputs to their original values. Pop-up form provides the user the ability to reset only selected cells or the entire worksheet.			
Override - Agricultural	This worksheet provides the user the ability to modify select inputs to calculate Agricultural demand by Crop Group. Data is provided for Statewide, County and Administrative Basins on a monthly basis for 2007 and five year increments starting in 2010 through 2050. Skip Update Check Box: Allows user to turn off the automated calculation of cells calculated by Visual Basic (i.e. green cells). All cells are recalculated after each input cell is modified, unless check box is checked. When the user turns off Skip Update (i.e. unchecks box) the calculations are run. Reset Button: Provides the user an automated method to reset modified inputs to their original values. Pop-up form provides the user the ability to reset only selected cells or the entire worksheet. Agriculture only.			
Override - Agricultural Distribution	This worksheets contains two tables identifying the allocation of water demand by crop by county to each Administrative Basin. Skip Update Check Box: Allows user to turn off the automated calculation of cells calculated by Visual Basic (i.e. green cells). All cells are recalculated after each input cell is modified, unless check box is checked. When the user turns off Skip Update (i.e. unchecks box) the calculations are run. Reset Button: Provides the user an automated method to reset modified inputs to their original values. Pop-up form provides the user the ability to reset only selected cells or the entire worksheet. Agriculture only.			

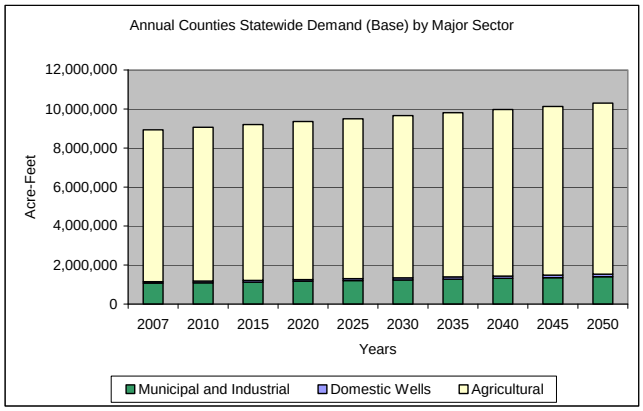
Screen Capture of Summary Output Menus

Graph and Table Parameter Selection

Selected Geographic Area	Statewide
Selected Name	Counties
Selected Month	Annual
Selected Crop Group	TOTAL
Selected Municipal/ Domestic Well Demand Type	Total
Display Units	Acre-Feet

Chart Types (Choose Option)

1. Demand	Line Chart
2. Demand by Major Sectors	Stacked Bar Chart
3. Demand for MDI Sectors	Stacked Bar Chart
4. Show Charts 1, 2, & 3	Show All
5. Base & Override Demand	Line Chart



Annual Counties Statewide Demand (Base) (Acre-Feet)

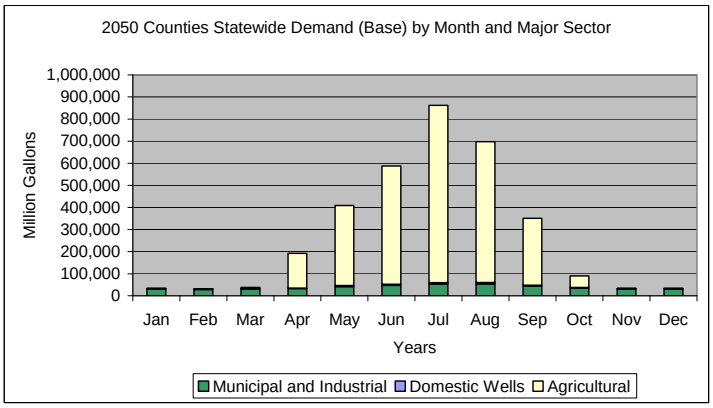
Years	Municipal Systems	Domestic Wells	Industrial	Agricultural	Total	Municipal and Industrial
2007	539,036	80,295	533,622	7,780,349	8,933,302	1,072,658
2010	559,123	83,242	533,622	7,880,804	9,056,791	1,092,745
2015	595,570	88,750	533,622	7,983,558	9,201,500	1,129,192
2020	634,641	94,600	535,084	8,088,667	9,352,992	1,169,725
2025	671,637	100,215	533,622	8,196,188	9,501,661	1,205,259
2030	709,440	105,917	533,622	8,306,180	9,655,160	1,243,062
2035	746,890	111,610	533,622	8,418,704	9,810,826	1,280,513
2040	786,675	117,749	535,084	8,533,822	9,973,330	1,321,759
2045	825,817	123,870	533,622	8,651,597	10,134,907	1,359,440
2050	868,885	130,566	533,622	8,772,096	10,305,170	1,402,508

Graph and Table Parameter Selection

Selected Geographic Area	Statewide
Selected Name	Counties
Selected Year	2050
Display Units	Million Gallons

Chart Types (Choose Option)

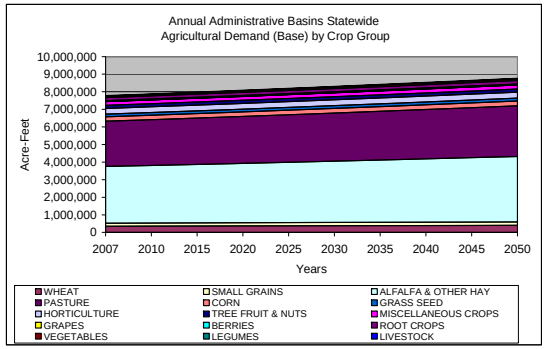
1. Demand	Line Chart
2. Demand by Major Sectors	Stacked Bar Chart
3. Show Charts 1 & 2	Show All
4. Base & Override Demand	Line Chart

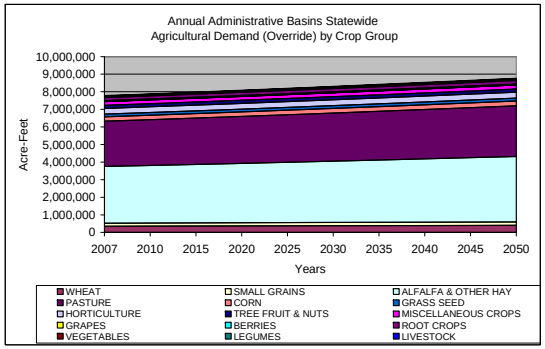


2050 Counties Statewide Demand (Base) by Month and Major Sector (Million Gallons)

Years	Municipal Systems	Domestic Wells	Industrial	Agricultural	Total	Municipal and Industrial
Jan	15,813	1,980	14,764	710	33,267	30,577
Feb	14,853	1,927	13,335	738	30,854	28,189
Mar	15,304	1,960	14,764	5,789	37,817	30,068
Apr	18,045	2,551	14,288	157,390	192,274	32,333
May	27,088	4,374	14,764	362,580	408,806	41,852
Jun	32,780	5,391	14,288	535,309	587,768	47,068
Jul	38,700	6,292	14,764	802,150	861,906	53,464
Aug	38,936	6,482	14,764	637,837	698,020	53,701
Sep	29,588	4,611	14,288	301,721	350,207	43,876
Oct	19,572	2,849	14,764	52,710	89,895	34,336
Nov	16,172	2,077	14,288	754	33,291	30,460
Dec	16,201	2,040	14,764	710	33,715	30,965

Graph and Table Parameter Selection	
Selected Geographic Area	Statewide
Selected Name	Administrative Basins
Selected Month	Annual
Display Units	Acre-Feet





Annual Administrative Basins Statewide Demand (Base) (Acre-Feet)

Years	WHEAT	SMALL GRAINS	ALFALFA & OTHER HAY	PASTURE	CORN	GRASS SEED	HORTICULTURE	TREE FRUIT & NUTS	MISCELLANEOUS CROPS	GRAPES	BERRIES	ROOT CROPS	VEGETABLES	LEGUMES	LIVESTOCK
2007	356,198	168,206	3,222,734	2,580,529	245,926	155,481	324,180	174,744	208,159	10,500	49,917	165,208	79,069	16,014	23,483
2010	360,904	170,765	3,273,446	2,610,823	248,962	156,389	325,459	175,247	210,265	10,549	49,863	168,132	79,942	16,304	23,753
2015	365,711	173,386	3,325,324	2,641,828	252,062	157,309	326,763	175,764	212,419	10,598	49,810	171,122	80,832	16,601	24,029
2020	370,620	176,071	3,378,397	2,673,561	255,227	158,243	328,092	176,294	214,622	10,647	49,760	174,180	81,738	16,903	24,310
2025	375,634	178,822	3,432,695	2,706,041	258,458	159,191	329,446	176,839	216,876	10,698	49,711	177,307	82,660	17,212	24,598
2030	380,756	181,639	3,488,248	2,739,284	261,757	160,152	330,825	177,398	219,182	10,749	49,663	180,506	83,601	17,527	24,892
2035	385,988	184,526	3,545,087	2,773,312	265,124	161,127	332,230	177,972	221,541	10,800	49,618	183,778	84,558	17,849	25,193
2040	391,332	187,484	3,603,246	2,808,143	268,562	162,116	333,662	178,560	223,954	10,852	49,575	187,123	85,534	18,177	25,500
2045	396,791	190,513	3,662,756	2,843,798	272,073	163,120	335,121	179,164	226,423	10,905	49,533	190,545	86,529	18,512	25,814
2050	402,367	193,618	3,723,653	2,880,296	275,657	164,138	336,607	179,784	228,949	10,959	49,493	194,045	87,541	18,854	26,135

This page left intentionally blank.

Screen Capture of a Portion of the Municipal Base Worksheet

		Name	Year	Population			Per Capita Water Use					
				Annual Growth Rate	Population Served	Total Population	Jan			Feb		
Order ID	Geographic Area						Total	Indoor	Outdoor	Total	Indoor	Outdoor
#	*Statewide, County, or Administrative Basin*	*Text*	*yyyy*	*%*	*# of People*	*# of People*	*gallons per day*	*gallons per day*	*gallons per day*	*gallons per day*	*gallons per day*	*gallons per day*
11	Statewide	Administrative Basins	2007	n/a	3,342,812	3,788,272	n/a	n/a	n/a	n/a	n/a	n/a
1	Statewide	Counties	2007	n/a	3,342,812	3,788,272	n/a	n/a	n/a	n/a	n/a	n/a
12	Statewide	Administrative Basins	2010	n/a	3,466,613	3,927,577	n/a	n/a	n/a	n/a	n/a	n/a
2	Statewide	Counties	2010	n/a	3,466,324	3,927,838	n/a	n/a	n/a	n/a	n/a	n/a
13	Statewide	Administrative Basins	2015	n/a	3,692,514	4,182,086	n/a	n/a	n/a	n/a	n/a	n/a
3	Statewide	Counties	2015	n/a	3,691,442	4,183,333	n/a	n/a	n/a	n/a	n/a	n/a
14	Statewide	Administrative Basins	2020	n/a	3,929,217	4,448,095	n/a	n/a	n/a	n/a	n/a	n/a
4	Statewide	Counties	2020	n/a	3,926,871	4,450,482	n/a	n/a	n/a	n/a	n/a	n/a
15	Statewide	Administrative Basins	2025	n/a	4,168,994	4,717,342	n/a	n/a	n/a	n/a	n/a	n/a
5	Statewide	Counties	2025	n/a	4,165,064	4,720,788	n/a	n/a	n/a	n/a	n/a	n/a
16	Statewide	Administrative Basins	2030	n/a	4,407,647	4,984,996	n/a	n/a	n/a	n/a	n/a	n/a
6	Statewide	Counties	2030	n/a	4,401,944	4,989,422	n/a	n/a	n/a	n/a	n/a	n/a
17	Statewide	Administrative Basins	2035	n/a	4,644,904	5,250,862	n/a	n/a	n/a	n/a	n/a	n/a
7	Statewide	Counties	2035	n/a	4,637,090	5,256,282	n/a	n/a	n/a	n/a	n/a	n/a
18	Statewide	Administrative Basins	2040	n/a	4,888,337	5,523,704	n/a	n/a	n/a	n/a	n/a	n/a
8	Statewide	Counties	2040	n/a	4,877,827	5,530,188	n/a	n/a	n/a	n/a	n/a	n/a
19	Statewide	Administrative Basins	2045	n/a	5,144,893	5,811,203	n/a	n/a	n/a	n/a	n/a	n/a
9	Statewide	Counties	2045	n/a	5,133,299	5,820,873	n/a	n/a	n/a	n/a	n/a	n/a
20	Statewide	Administrative Basins	2050	n/a	5,415,285	6,114,154	n/a	n/a	n/a	n/a	n/a	n/a
10	Statewide	Counties	2050	n/a	5,404,495	6,129,463	n/a	n/a	n/a	n/a	n/a	n/a
21	County	Baker	2007	n/a	13,105	16,321	73	73	0	87	87	0
31	County	Benton	2007	n/a	79,648	87,686	99	99	0	101	101	0
41	County	Clackamas	2007	n/a	323,579	384,564	84	84	0	87	87	0
51	County	Clatsop	2007	n/a	30,631	37,292	99	99	0	99	99	0
61	County	Columbia	2007	n/a	38,492	48,762	85	85	0	87	87	0
71	County	Coos	2007	n/a	52,294	64,153	94	94	0	95	95	0
81	County	Crook	2007	n/a	19,491	26,166	67	67	0	88	88	0
91	County	Curry	2007	n/a	15,346	22,748	81	81	0	83	83	0
101	County	Deschutes	2007	n/a	129,742	159,002	81	81	0	105	105	0
111	County	Douglas	2007	n/a	76,047	106,038	84	84	0	88	88	0
121	County	Gilliam	2007	n/a	1,436	1,512	92	92	0	85	85	0
131	County	Grant	2007	n/a	5,899	6,784	77	77	0	86	86	0
141	County	Harney	2007	n/a	5,380	7,671	75	75	0	87	87	0
151	County	Hood River	2007	n/a	15,349	21,722	68	68	0	87	87	0
161	County	Jackson	2007	n/a	180,368	204,483	127	127	0	122	122	0
171	County	Jefferson	2007	n/a	12,755	23,150	59	59	0	88	88	0
181	County	Josephine	2007	n/a	67,067	88,206	120	120	0	117	117	0
191	County	Klamath	2007	n/a	44,915	67,497	62	62	0	88	88	0
201	County	Lake	2007	n/a	5,125	7,706	62	62	0	88	88	0
211	County	Lane	2007	n/a	308,761	352,600	92	92	0	94	94	0

Screen Capture of a Portion of the Agricultural Base Worksheet

☑ Skip Updates			Year	Crop Group	Acreage		Crop Irrigation Requirement									
							Jan		Feb		Mar		Apr		May	
Order ID	Geographic Area	Name			% of Previous Time Period	Acreage	% of Previous Time Period	Water Use	% of Previous Time Period	Water Use	% of Previous Time Period	Water Use	% of Previous Time Period	Water Use	% of Previous Time Period	Water Use
#	Statewide, County, or (3) AB	Text	yyyy	(name)	%	Acres	%	inches	%	inches	%	inches	%	inches	%	inches
321	County	Baker	2007	WHEAT	n/a	8,030	n/a	0.00	n/a	0.00	n/a	0.04	n/a	0.81	n/a	2.18
322	County	Baker	2007	SMALL GRAINS	n/a	1,677	n/a	0.00	n/a	0.00	n/a	0.05	n/a	1.08	n/a	2.93
323	County	Baker	2007	ALFALFA & OTHER HAY	n/a	75,216	n/a	0.00	n/a	0.00	n/a	0.00	n/a	2.34	n/a	4.91
324	County	Baker	2007	PASTURE	n/a	56,412	n/a	0.00	n/a	0.00	n/a	0.15	n/a	2.20	n/a	3.33
325	County	Baker	2007	CORN	n/a	1,220	n/a	0.00	n/a	0.00	n/a	0.07	n/a	1.38	n/a	3.72
326	County	Baker	2007	GRASS SEED	n/a	0	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00
327	County	Baker	2007	HORTICULTURE	n/a	0	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00
328	County	Baker	2007	TREE FRUIT & NUTS	n/a	0	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00
329	County	Baker	2007	MISCELLANEOUS CROPS	n/a	254	n/a	0.00	n/a	0.00	n/a	0.05	n/a	0.90	n/a	2.43
330	County	Baker	2007	GRAPES	n/a	0	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00
331	County	Baker	2007	BERRIES	n/a	0	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00
332	County	Baker	2007	ROOT CROPS	n/a	2,948	n/a	0.00	n/a	0.00	n/a	0.05	n/a	1.04	n/a	2.80
333	County	Baker	2007	VEGETABLES	n/a	0	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00	n/a	0.00
334	County	Baker	2007	LEGUMES	n/a	254	n/a	0.00	n/a	0.00	n/a	0.04	n/a	0.76	n/a	2.05
335	County	Baker	2007	LIVESTOCK	n/a	980	n/a	1.00	n/a	1.00	n/a	1.00	n/a	1.00	n/a	1.00
336	County	Baker	2007	TOTAL	n/a	146,990	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
337	County	Baker	2010	WHEAT	103%	8,281	100%	0	100%	0	100%	0	100%	1	100%	2
338	County	Baker	2010	SMALL GRAINS	103%	1,730	100%	0	100%	0	100%	0	100%	1	100%	3
339	County	Baker	2010	ALFALFA & OTHER HAY	103%	77,570	100%	0	100%	0	100%	0	100%	2	100%	5
340	County	Baker	2010	PASTURE	103%	58,178	100%	0	100%	0	100%	0	100%	2	100%	3
341	County	Baker	2010	CORN	103%	1,258	100%	0	100%	0	100%	0	100%	1	100%	4
342	County	Baker	2010	GRASS SEED	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
343	County	Baker	2010	HORTICULTURE	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
344	County	Baker	2010	TREE FRUIT & NUTS	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
345	County	Baker	2010	MISCELLANEOUS CROPS	103%	262	100%	0	100%	0	100%	0	100%	1	100%	2
346	County	Baker	2010	GRAPES	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
347	County	Baker	2010	BERRIES	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
348	County	Baker	2010	ROOT CROPS	103%	3,040	100%	0	100%	0	100%	0	100%	1	100%	3
349	County	Baker	2010	VEGETABLES	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
350	County	Baker	2010	LEGUMES	103%	262	100%	0	100%	0	100%	0	100%	1	100%	2
351	County	Baker	2010	LIVESTOCK	103%	1,011	100%	1	100%	1	100%	1	100%	1	100%	1
352	County	Baker	2010	TOTAL	n/a	151,591	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
353	County	Baker	2015	WHEAT	103%	8,540	100%	0	100%	0	100%	0	100%	1	100%	2
354	County	Baker	2015	SMALL GRAINS	103%	1,784	100%	0	100%	0	100%	0	100%	1	100%	3
355	County	Baker	2015	ALFALFA & OTHER HAY	103%	79,998	100%	0	100%	0	100%	0	100%	2	100%	5
356	County	Baker	2015	PASTURE	103%	59,999	100%	0	100%	0	100%	0	100%	2	100%	3
357	County	Baker	2015	CORN	103%	1,297	100%	0	100%	0	100%	0	100%	1	100%	4
358	County	Baker	2015	GRASS SEED	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
359	County	Baker	2015	HORTICULTURE	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
360	County	Baker	2015	TREE FRUIT & NUTS	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
361	County	Baker	2015	MISCELLANEOUS CROPS	103%	270	100%	0	100%	0	100%	0	100%	1	100%	2
362	County	Baker	2015	GRAPES	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
363	County	Baker	2015	BERRIES	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
364	County	Baker	2015	ROOT CROPS	103%	3,135	100%	0	100%	0	100%	0	100%	1	100%	3
365	County	Baker	2015	VEGETABLES	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
366	County	Baker	2015	LEGUMES	103%	270	100%	0	100%	0	100%	0	100%	1	100%	2
367	County	Baker	2015	LIVESTOCK	103%	1,042	100%	1	100%	1	100%	1	100%	1	100%	1
368	County	Baker	2015	TOTAL	n/a	156,336	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
369	County	Baker	2020	WHEAT	103%	8,808	100%	0	100%	0	100%	0	100%	1	100%	2
370	County	Baker	2020	SMALL GRAINS	103%	1,840	100%	0	100%	0	100%	0	100%	1	100%	3
371	County	Baker	2020	ALFALFA & OTHER HAY	103%	82,502	100%	0	100%	0	100%	0	100%	2	100%	5
372	County	Baker	2020	PASTURE	103%	61,876	100%	0	100%	0	100%	0	100%	2	100%	3
373	County	Baker	2020	CORN	103%	1,338	100%	0	100%	0	100%	0	100%	1	100%	4
374	County	Baker	2020	GRASS SEED	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
375	County	Baker	2020	HORTICULTURE	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
376	County	Baker	2020	TREE FRUIT & NUTS	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
377	County	Baker	2020	MISCELLANEOUS CROPS	103%	279	100%	0	100%	0	100%	0	100%	1	100%	2
378	County	Baker	2020	GRAPES	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
379	County	Baker	2020	BERRIES	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
380	County	Baker	2020	ROOT CROPS	103%	3,233	100%	0	100%	0	100%	0	100%	1	100%	3
381	County	Baker	2020	VEGETABLES	103%	0	100%	0	100%	0	100%	0	100%	0	100%	0
382	County	Baker	2020	LEGUMES	103%	279	100%	0	100%	0	100%	0	100%	1	100%	2
383	County	Baker	2020	LIVESTOCK	103%	1,075	100%	1	100%	1	100%	1	100%	1	100%	1
384	County	Baker	2020	TOTAL	n/a	161,229	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

APPENDIX E

Instream Data Processing: Hydropower and Ecological Uses

Table E-1a. OWRD Regulated Dams with Hydropower as Beneficial Use

DAM_NAME	STATE_ID	COUNTY	RIVER	OWNER_NAME	PURPOSES	Dam Height (ft) DAM_HEIGHT	Discharge Rating (cfs) MAX_DISCHG	Storage Volume (ac-ft) NORML_STOR	Surrogate Power Generation Rating Potential Megawatts
McNary Dam	Corp	Umatilla	Columbia River	DAEN/NPP	HCNIRS	158	2,200,000	1,350,000	14,040
The Dalles Dam	Corp	Wasco	Columbia River	DAEN/NPP	HNRI	117	2,290,000	277,000	10,822
John Day Dam	Corp	Sherman	Columbia River	DAEN/NPP	HCNR	113	2,250,000	530,000	10,270
Bonneville Dam	Corp	Multnomah	Columbia River	DAEN/NPP	HNR	110	1,600,000	277,000	7,109
Detroit Res	R-1625	Linn	North Santiam River	DAEN/NPP	HCRINO	450	176,000	455,000	3,199
Lookout Point	R-1625	Lane	Middle Fork Willamette	DAEN/NPP	CINHRO	276	270,000	358,900	3,010
Lost Creek Res	R-8141	Jackson	Rogue River	DAEN/NPP	CHSR	345	158,000	318,430	2,202
Hills Creek Res	R-5363	Lane	M. Fk. Willamette Riv.	DAEN/NPP	HCISRNO	341	141,600	156,000	1,950
Green Peter Reservoir	R-5363	Linn	Middle Santiam River	DAEN/NPP	CHRINO	378	110,000	428,000	1,679
Cougar Res	R-5363	Lane	S. Fk. McKenzie River	DAEN/NPP	HCIRNSO	519	76,000	219,000	1,593
North Fork Arch (Clackamas)	HE-202	Clackamas	Clackamas River	City of Portland	H	207	179,000	10,000	1,497
Brownlee	HE-188	Baker	Snake River	Idaho Power Co.	H	400	84,500	1,426,700	1,365
Dexter	Corp	Lane	Middle Fk. Willamette River	DAEN/NPP	HR	117	270,000	22,200	1,276
Oxbow	HE-161	Baker	Snake River	Idaho Power Co.	H	205	150,000	58,200	1,242
Big Cliff Dam	Corp	Linn	North Santiam River	DAEN/NPP	H	141	176,000	2,630	1,002
Foster Reservoir	R-5363	Linn	South Santiam River	DAEN/NPP	HCRINO	126	195,000	60,800	992
Round Butte Dam	HE-217	Jefferson	Deschutes and Metolius Rivers	Portland General Electric	HR	440	45,400	535,000	807
Willamette Falls	PC-537	Clackamas	Willamette River	Publishers Paper	H	45	400,000	100	727
Fall Creek Res	R-5363	Lane	Fall Creek	DAEN/NPP	CHINRSO	205	82,400	125,000	682
River Mill Dam	PC-116	Clackamas	Clackamas River	Portland General Electric	H	90	179,000	12,200	651
Faraday Div. Dam	HE-203	Clackamas	Clackamas River	Portland General Electric	H	84	179,000	560	607
Pelton Dam	HE-222	Jefferson	Deschutes River	Portland General Electric	H	204	45,400	37,300	374
Faraday Forebay	HE-203	Clackamas	Clackamas River	Portland General Electric	H	44	150,000	675	267
Leaburg Dam	PC-724	Lane	McKenzie River	City of Eugene	H	58	96,000	345	225
Pelton Regulating Dam	HE-222	Jefferson	Deschutes River	Portland General Electric	H	78	45,400	3,270	143
Lemolo #1	HE-21	Douglas	North Umpqua River	Pacific Power and Light	HR	120	19,000	14,650	92
Soda Springs	HE-23	Douglas	North Umpqua River	Pacific Power and Light	H	128	17,000	710	88
Smith River	R-5117	Linn	Smith R. and McKenzie R.	Eugene Water & Electric Board	H	228	9,000	15,000	83
J. C. Boyle	HE-180	Klamath	Klamath River	Pacific Power and Light	HR	58	31,500	3,377	74
Trail Br. Reg. Res.	R-2364	Linn	McKenzie & Smith Rivers	Eugene Water & Electric Board	H	96	19,000	2,263	74
Big Sandy Res. (Marmont Dam)	PC-117	Clackamas	Big Sandy River	Portland General Electric	HS	40	45,000	100	73
Timothy Lake	HE-186	Clackamas	Oak Grove Fork Clackamas River	Portland General Electric	HR	110	14,000	66,000	62
Toketee Falls	HE-23	Douglas	North Umpqua River	PacificCorp (PP&L)	HR	58	20,000	1,400	47
Keno Dam	HE-231	Klamath	Klamath River	Pacific Power and Light	HR	31	35,000	18,500	44
N. Fork Dam	PC-421	Jackson	N. Fork Rogue River	Pacific Power and Light	H	58	13,800	250	32
Lake Harriet	HE-186	Clackamas	Oak Grove Fork Clackamas River	Portland General Electric	H	75	8,000	400	24
Carmen Diversion	R-2138	Linn	McKenzie River	Eugene Water & Electric Board	H	44	9,000	261	16
Slide Creek Dam	HE-23	Douglas	North Umpqua River	PacificCorp (PP&L)	H	45	8,600	50	16
Steidl Dam (N. Unit Div.)	PC-134	Deschutes	Deschutes River	Central Oregon Irrigation District	H	33	10,000	30	13
Upper Klamath Lake	PC-35	Klamath	Link River	DOI/USBR	HRI	22	14,000	873,500	12
Fish Creek Diversion	HE-20	Douglas	Fish Creek	PacificCorp (PP&L)	H	14	13,500	71	8

Table E-1a. OWRD Regulated Dams with Hydropower as Beneficial Use

						Dam Height (ft)	Discharge Rating (cfs)	Storage Volume (ac-ft)	Surrogate Power Generation Rating Potential
DAM_NAME	STATE_ID	COUNTY	RIVER	OWNER_NAME	PURPOSES	DAM_HEIGHT	MAX_DISCHG	NORML_STOR	Megawatts
Keene Creek Diversion	R-2210	Jackson	Keene Creek	USBR (Talent Irrigation District)	IH	67	2,650	339	7
Clearwater #1	HE-19	Douglas	Clearwater River	Pacific Power and Light	H	17	9,500	152	7
Howard Prairie	R-2210	Jackson	Trib's of S Fk. Little Butte C	DOI/USBR	IHCR	100	1,540	62,100	6
Wallowa Lake Res.	R-5018	Wallowa	Wallowa River	Associated Ditch Companies	IHS	39	3,420	49,257	5
Fish Creek Forebay (Douglas)	HE-20	Douglas	Fish Creek via canal	PacificCorp (PP&L)	H	14	4,000	94	2
Bend Power	PC-129	Deschutes	Deschutes River	Pacific Power and Light	H	16	3,000	100	2
Lake Oswego	PC-97	Clackamas	Tualatin River (offstream)	Lake Oswego Corporation	HR	32	1,400	9,800	2
Frog Lake	HE-186	Clackamas	Oak Grove Fork Clackamas River	Portland General Electric	H	70	600	460	2
Lake Roslyn	PC-117	Clackamas	Big and Little Sandy Rivers	Portland General Electric	H	45	800	2,011	1
Lemolo #2 Forebay	HE-21	Douglas	North Umpqua River	Pacific Power and Light	H	32	565	127	1
Walterville Power Intake	PC-545	Lane	McKenzie River	Eugene Water & Electric Board	H	60	300	100	1
N. Fork Reg. Dam	PC-739	Jackson	N. Fork Rogue River	Pacific Power and Light	H	50	275	309	1
Clearwater #2 Forebay	HE-19	Douglas	Clearwater River	Pacific Power and Light	H	24	250	68	0.24
S. Fork Div. Dam	PC-721	Jackson	S. Fork Rogue River	Pacific Power and Light	H	29	150	17	0.18
Clearwater #1 Forebay	HE-19	Douglas	Clearwater River	Pacific Power and Light	H	17	200	154	0.14
Walterville Pumped S. Pond	R-1640	Lane	McKenzie Riv. & Jameson Cr.	Eugene Water & Electric Board	H	12	20	345	0.01

Notes:
Purpose of Use Codes: I - irrigation, H - hydroelectric, C - flood control and storm water management, N - navigation, S - water supply, R - recreation, P - fire protection, stock, or small farm pond, D - debris control, T - tailings, O - other

Surrogate Power Generation Rating calculated by multiplying dam height (ft) X discharge rating (cfs) x 0.00008078 conversion factor X 50% efficiency

Table E-1b. OWRD Regulated Dams without Hydropower as Beneficial Use (Potential Power Generation Rate > 1 MW)

						Dam Height (ft)	Discharge Rating (cfs)	Storage Volume (ac-ft)	Surrogate Power Generation Rating Potential
DAM_NAME	STATE_ID	COUNTY	RIVER	OWNER_NAME	PURPOSES	DAM_HEIGHT	MAX_DISCHG	NORML_STOR	Megawatta
Hells Canyon	HE-189	Wallowa	Snake River	Idaho Power Co.	P	320	210,000	183,000	2,714
Applegate Lake	R-7810	Jackson	Applegate River	DAEN/NPP	ICR	242	93,800	82,000	917
Blue River Dam	R-5363	Lane	Blue River	DAEN/NPP	CR	312	53,000	89,500	668
Dorena	R-1625	Lane	Row River	DAEN/NPP	CINRO	145	97,500	77,500	571
Owyhee	R-1764	Malheur	Owyhee River	DOI/WPRS	ICR	340	40,000	1,120,000	549
Willow Creek	R-10880	Morrow	Willow Creek	DAEN/NPP	RI	165	72,000	13,200	480
Galesville Res.	R-9964	Douglas	Cow Creek	Douglas County Natural Resources Division	RISF	167	43,970	42,225	297
Bull Run Dam 1	PC-865	Multnomah	Bull Run River	Clarence Hilbrick	S	194	25,000	26,640	196
Cottage Grove	R-1625	Lane	Coast Fork Willamette	DAEN/NPP	CIRNO	103	40,800	33,000	170
Bull Run Dam 2	PC-864	Clackamas	Bull Run River	Clarence Hilbrick	S	125	27,882	20,500	141
Emigrant	R-2209	Jackson	Hyatt & Howard Prairie Res's,	DOI/USBR	ICRO	204	11,300	40,500	93
Thief Valley Res.	R-667	Baker	Powder River	DOI/WPRS	I	66	34,000	17,400	91
Fern Ridge	R-1625	Lane	Long Tom River	DAEN/NPP	CR	49	45,000	116,800	89
Wolf Creek Res.	R-5776	Union	Wolf Creek and Anthony Creek	Powder Valley Water Control Dist.	IR	125	17,370	10,800	88
Willow Creek 3	9-219	Malheur	Willow Creek	Orchard Water Company	I	110	17,000	20,400	76
Carty Res.	R-6276	Morrow	Columbia River (cooling)	Portland General Electric	IO	80	22,000	129,000	71
Berry Creek Dam	R-7256	Douglas	Berry Creek	Water Resources Survey	SI	140	12,000	11,250	68
McKay Res.	R-584	Umatilla	McKay and Birch Creeks	DOI/WPRS	IC	165	10,000	73,800	67
Prineville Res.	R-2223	Crook	Crooked River	DOI/WPRS	ICR	188	8,120	155,000	62
Agency Valley Res	R-671	Malheur	N. Fk. Malheur River	DOI/WPRS	ICR	110	12,000	59,900	53
Ochoco Res.	R-528	Crook	Ochoco Creek	Ochoco Irrigation District	IC	130	10,000	47,500	53
Three Miles Falls (Div.)	408	Umatilla	Umatilla River	DOI/WPRS	I	28	38,000	300	43
Silver Creek	R-5948	Marion	Silver Creek	City of Silverton	S	65	16,000	1,300	42
Horsefly (Gerber Res)	5-107	Klamath	Miller Creek	DOI/USBR	IR	88	10,000	94,500	36
Mercer Res.	R-5755	Polk	Rickreall Creek	City of Dallas	S	79	8,700	1,550	28
Unity Reservoir	R-726	Baker	Burnt River	DOI/WPRS	IR	67	10,000	50,000	27
City of Portland #1	In-Line	Multnomah	Bull Run River (offstream)	City of Portland #1	S	30	21,000	37	25
Bully Creek Res	R-4456	Malheur	Bully Creek & Malheur River	DOI/WPRS	ICR	121	5,000	31,628	24
Cold Springs Res.	3-242	Umatilla	Umatilla River	DOI/WPRS	IO	100	6,000	44,600	24
Youngs River Res.	R-2568	Clatsop	Youngs River (not built 2/1/85	City of Astoria	S	81	7,000	12,000	23
Lost River Div.	None	Klamath	Lost River	DOI/USBR	IR	41	13,000	1,400	22
Wickiup Res.	R-1677	Deschutes	Deschutes River	North Unit Irrigation District	IR	100	5,000	200,000	20
Trask River	R-5773	Washington	M.F. of N.F. Trask River	City of Hillsboro	S	72	5,600	4,000	16
Crow Creek Res.	R-4988	Wasco	S.F. Mill Creek	City of The Dalles	S	113	2,500	955	11
Agate Dam	R-4563	Jackson	Dry Creek, Antelope Cr.& Other	DOI/USBR	IRO	77	3,600	4,782	11
Savage Rapids Dam	PC-734	Jackson	Rogue River	Grants Pass Irrigation District	IR	34	8,000	1,500	11
Willow Creek (Jackson)	R-118	Jackson	Willow & Four Bit Creeks	City of Medford	S	54	4,634	7,500	10
Thompson Valley Div. Res	R-680	Lake	Silver and W. Fk. Silver Creek	John Monfore Weyerhaeuser Co.	I	48	5,000	460	10
Merwin Res. 2	R-3258	Crook	Watson Creek	Gale Merwin	I	74	3,000	174	9
Canyonville Res.	R-8323	Douglas	West Fork Canyon Creek	City of Canyonville	S	58	3,783	300	9

Table E-1b. OWRD Regulated Dams without Hydropower as Beneficial Use (Potential Power Generation Rate > 1 MW)

						Dam Height (ft)	Discharge Rating (cfs)	Storage Volume (ac-ft)	Surrogate Power Generation Rating Potential
DAM_NAME	STATE_ID	COUNTY	RIVER	OWNER_NAME	PURPOSES	DAM_HEIGHT	MAX_DISCHG	NORML_STOR	Megawatta
Olive Lake	10-495	Grant	Upper & Lower Lake Creeks	Cal. Pacific Utilities	R	38	5,650	4,600	9
Hyatt Reservoir	R-214	Jackson	Keene Creek	DOI/USBR (Talent Irrigation District)	IS	47	3,800	16,200	7
Drews Res	C-47468	Lake	Drews Creek	William Wales	I	60	2,900	62,500	7
Cottonwood - Lake Co.	R-7802	Lake	Cottonwood Creek & trib	Lakeview Water Users Inc.	I	60	2,800	8,740	7
Reeder Gulch Res.	R-596	Jackson	Ashland Creek	City of Ashland	S	110	1,500	800	7
Currant Creek	R-8452	Wasco	Currant Creek	Rajneesh Neo-Sannyas International Commune	I	82	2,000	1,020	7
Anderson-Rose Div.	None	Klamath	Lost River	DOI/USBR	I	16	10,000	450	6
Bear Creek Res. Site 3	R-5652	Douglas	Bear Creek	City of Drain	S	55	2,750	300	6
Haskins Cr. Imponding Res.	R-612	Yamhill	Haskins Creek	City of McMinnville	S	72	2,100	325	6
Mason	R-5083	Baker	Powder River	DOI/WPRS	ICRO	167	900	114,000	6
Mill Creek Dam	R-5132	Lincoln	Mill Creek	City of Toledo	S	70	2,000	250	6
Willow Valley Res	R-2631	Klamath	E. Fk. Lost River	Willow Valley Land & Cattle Company	I	34	4,050	2,038	6
North Fork (Benton)	R-2287	Benton	N. Fk. Rock Creek	City of Corvallis	S	81	1,650	257	5
Lake Creek	R-3232	Jackson	Lake Creek	Cascade Ranches	I	77	1,690	1,360	5
Malone Div. Dam	None	Klamath	Lost River	DOI/USBR	I	32	4,000	500	5
Whited Res.	R-72	Baker	So. Fork of Burnt River	George and Florence Hardy	IS	45	2,750	700	5
Painted Hills Res.	R-7015	Wheeler	Bear and Bridge Creeks	Bill Spoo	I	42	2,884	800	5
Thompson Valley Res	R-4461	Lake	Silver Creek	Silver Lake Irrigation Dist.	I	48	2,514	19,660	5
Siltcoos Lake	R-2341	Lane	Siltcoos River	International Paper Co.	O	12	10,000	15,070	5
Big Creek Res. 2	R-5134	Lincoln	Big Creek	City of Newport	S	56	2,000	970	5
Rowe Creek Dam	R-930	Wheeler	Rowe Creek	Thomas Cole / Diamond Ranch	I	60	1,800	387	4
Cottonwood (Drewsey)	R-4699	Harney	Cottonwood Creek	Otis Valley Irrigation	I	73	1,450	3,700	4
Gold Ray Dam	PC-31	Jackson	Rogue River	Jackson County Parks & Recreation	R	35	3,000	100	4
Osbore Creek	R-3424	Jackson	Osborne Creek	Cascade Ranches	I	60	1,725	438	4
Chickahominy Creek	R-1256	Harney	Chickahominy Creek	ODF&W	I	36	2,862	7,228	4
Wampler-Werth	In-Line	Crook	C.O.I.	Wampler-Werth	S	20	5,149	90	4
Tahkenitch Lake	R-2342	Douglas	Tahkenitch Creek	International Paper Co	O	10	10,000	16,580	4
Fish Lake (Jackson)	R-50	Jackson	Fish Lake & Trib	Medford Irrigation District	IR	50	2,000	22,500	4
Cooper Creek Reservoir	R-4965	Douglas	Cooper Creek	Sutherlin Water Control District	RS	84	1,100	3,900	4
N. Fk. Indian Cr. Res	R-1004	Malheur	N. Fk. Indian Cr.	Griffith Ford Inc.	I	51	1,800	580	4
Four Mile Lake Dam	R-50	Klamath	Four Mile Lake & tribs	Medford Irrigation District	IS	45	2,000	33,000	4
Woolfold Res	R-1828	Jackson	School House Creek	Ira V. Woolfolk	I	47	1,862	480	4
Fishawk Lake	R-3982	Clatsop	Fishawk Creek	Fishhawk Lake Recreation Club, Inc.	R	35	2,500	982	4
Salmon Creek Res.	R-8346	Baker	Salmon Creek	Bob Harrell	I	41	2,044	255	3
Warmsprings Res.	R-457	Malheur	Middle Fork Malheur River	Warm Springs Irrigation District / USBR	I	100	810	192,400	3
Skookum Lake Res.	R-4532	Tillamook	Fawcett Creek	Tillamook Water Commission	S	40	2,000	700	3
Crane Prairie	R-1687	Deschutes	West Fork Deschutes River	Central Oregon Irrigation District	IR	32	2,500	55,330	3
Jimmy Creek Res.	R-8192	Union	Jimmy Creek	Seven Diamond Ranch	I	42	1,858	675	3
South Fork Little Butte		Jackson			I	20	3,900	10	3
Yankee Res (Gardener Res)	R-1184	Jackson	Yankee Creek	Victor E. Gardener	I	55	1,418	925	3
Mt. Hood Comm. Col. Res.	R-5085	Multnomah	Kelly Creek	Mt. Hood Community College	I	58	1,340	10	3
Upper Pony Creek	R-1064	Coos	Pony Creek	Coos Bay-North Bend Water Board	S	45	1,700	1,680	3

Table E-1b. OWRD Regulated Dams without Hydropower as Beneficial Use (Potential Power Generation Rate > 1 MW)

						Dam Height (ft)	Discharge Rating (cfs)	Storage Volume (ac-ft)	Surrogate Power Generation Rating Potential
DAM_NAME	STATE_ID	COUNTY	RIVER	OWNER_NAME	PURPOSES	DAM_HEIGHT	MAX_DISCHG	NORML_STOR	Megawatta
Betty Jane Deardorff	R-5437	Clackamas	Little Coal Creek	Gary Deardorff	O	65	1,170	1,030	3
Stinking Water Creek	R-5601	Harney	Stinking Water Creek	John Stringer	I	71	1,000	2,405	3
DeRaeve Res.	R-6154	Yamhill	Ash Swale	Philip R. Olson	I	14	5,000	93	3
Bull Prairie Res.	R-2455	Grant	Wilson Creek	ODF&W	R	47	1,480	168	3
Pine Hollow Res.	R-5250	Wasco	Badger Cr. and Pine Hollow Cr.	Pine Hollow Corp. Inc., Dept Of Fish & Wildlife	IR	65	1,060	4,750	3
Kern Brothers Res	R-959	Harney	Dry Krumbo Creek	Hammond Ranches	I	51	1,350	2,700	3
Cutsforth Dam	R-7820	Morrow	Rasmus Meadow Creek	O.W. Cutsforth	S	18	3,773	70	3
Kinnan, Frank Res.	R-4739	Douglas	Middle Fork Coquille River	Dan Chamness	R	45	1,500	395	3
Harrison	R-4951	Jackson	Lost Cr., Harrison Cr., and ot	Cascade Ranches	I	26	2,489	234	3
Rock Creek, Upper	R-836	Harney	Rock Creek	John Lagler	I	45	1,356	5,818	2
McGuire Res	R-5561	Yamhill	Nestucca River	McMinnville Water & Light	S	74	820	3,550	2
Bull Run Lake Dam	In-Line	Multnomah	Bull Run River	City of Portland	S	55	1,100	10,000	2
Allen Creek Res	R-2000	Crook	Allen Creek	Hudspeth Land & Livestock Co.	I	78	750	2,189	2
Panther Creek Res.	R-5527	Yamhill	Panther Creek	City of Carlton	S	49	1,180	75	2
Willard's Pool	R-948	Marion	Powers Creek	Robert M. & Deanne E. Whitmarsh	R	39	1,463	388	2
Crescent Lake	R-2744	Klamath	Crecent Lake	DOI/USBR	IR	38	1,500	86,050	2
Pilcher Creek Res.	R-8353	Union	Anthony and Pilcher Creeks	Powder Valley Water Control District	I	110	514	5,910	2
Shaw Res.	R-1810	Union	Little, Dry, & Gussie Creeks	Robert Koater	I	48	1,140	504	2
Mompano Reservoir	R-5444	Clackamas	Abernethy Creek	Beaver Lake Development, Inc.	OO	39	1,400	780	2
Fopiano Res.	R-1986	Wheeler	North Fopiano & South Fopiano	Lily F. Collins	I	36	1,500	200	2
Haystack Equalizing Pond	R-1754	Jefferson	Deschutes River	North Unit Irrigation District	I	91	555	6,000	2
Parsnip Creek Res	R-2226	Malheur	Parsnip Creek	Jaca Brothers	I	25	2,000	181	2
Renner Dam	R-2462	Lake	Dry Creek	Pacific American Development Co.	I	45	1,100	3,270	2
Moores Hollow Res	R-3525	Malheur	Moores Hollow	Dick Dehaven	IC	35	1,400	1,241	2
Bear Creek	R-4842	Clatsop	Bear Creek	City of Astoria	S	90	530	700	2
Hult Log Storage Pond	R-965	Lane	Upper Lake Creek	Bohemia	O	34	1,356	481	2
Rock Creek Res.	R-780	Wasco	Rock, N.Fk.Gate , & Threemile	Rock Creek District Improvement Company	I	51	904	1,280	2
Murphy Dam	R-1005	Malheur	Bendire Creek	James F. Murphy	I	60	760	1,203	2
Randall Res. 3	R-6562	Klamath	Cy's Branch	Louis E. Randall	I	40	1,130	420	2
Walch Dam	R-1459	Jackson	Indian & Dyer Creeks+Bear Gulc	Hermit Falk	I	65	691	1,150	2
Canyon Creek Meadows	R-2872	Grant	Canyon Creek	ODF&W	R	56	800	400	2
Sevan Lake	R-6091	Lake	Silver Lake, Trib to	John Detus	R	40	1,116	789	2
Vaughn Res	R-2076	Malheur	S. Fk. Indian Creek	Griffith Ford Inc.	I	64	675	825	2
Bradshaw	R-4747	Jackson	Lost Creek, Harrison Creek and	Merton Bradshaw	I	47	900	785	2
Guano Slough (BLM)	R-636	Lake	Guano Slough	DOI/BLM	I	14	2,900	300	2
Camp Creek Res.	R-47	Baker	Camp Creek & Bull Run Creek	Martin Grier	I	45	900	1,700	2
Bonny View	R-6551	Crook	Horse Heaven Creek	Gill Cattle Company	I	38	1,064	484	2
Watson Reservoir (Merwin #3)	R-5707	Crook	Watson Creek	George J. Isadore	I	32	1,250	2,102	2
Crowley Res.	R-709	Malheur	Big Crowley Creek	R.J. Bundguard	I	90	420	3,700	2
Shipler Reservoir	R-8449	Curry	Big Creek	Shipler Land Company	IO	23	1,640	250	2
Dick Dam No. 1	R-867	Crook	Lost Creek	Mike Munson	I	28	1,343	120	2
Winchester Dam	PC-867	Douglas	North Umpqua River	Winchester Water Control Dist.	R	17	2,200	700	2

Table E-1b. OWRD Regulated Dams without Hydropower as Beneficial Use (Potential Power Generation Rate > 1 MW)

						Dam Height (ft)	Discharge Rating (cfs)	Storage Volume (ac-ft)	Surrogate Power Generation Rating Potential
DAM_NAME	STATE_ID	COUNTY	RIVER	OWNER_NAME	PURPOSES	DAM_HEIGHT	MAX_DISCHG	NORML_STOR	Megawatta
Moon Res.	R-5266	Harney	Silver Creek	Girard Perkins/Gary Marshall	I	38	974	5,650	1
Indian Lake Dam (Umatilla)	B.I.A.	Umatilla	Jennings Creek	BIA	R	50	740	1,214	1
Pony Creek (Lower)	R-10888	Coos	Pony Creek	Coos Bay - North Bend Water Board	S	32	1,150	400	1
Griffin Creek Dam	R-1312	Harney	Griffin Creek	Joel C. Sword	I	44	824	475	1
Antelope Flat	R-2657	Crook	Bear & Faught CR's. & 2 tribs	William R. McCormack	I	33	1,090	1,793	1
Whispering Winds	R-5807	Benton	Burgett Creek	Girl Scout Camp	R	25	1,400	60	1
Bear Creek Res.	R-8369	Crook	Bear Creek	William McCormick	I	63	554	610	1
Mainline 1	R-4871	Crook	Maury Creek	Art Smith/L.S. Ranch	I	57	611	445	1
Ereno's	R-5371	Harney	Willow Creek	ODF&W	IRO	49	700	1,953	1
Fisher-Joe Res.	R-1468	Crook	Lytle Creek	Verne Baxter	I	51	669	508	1
Rock Quarry Canyon Dam	R-899	Harney	Rock Quarry Canyon	Hoyt & Sons Ranches	I	27	1,249	439	1
Clear Branch-Laurance Lake	R-4862	Hood River	Clear Branch	Middle Fork Irrigation District	IR	109	308	3,550	1
Munn Res.	R-857	Baker	Middle Fork Burnt River	Ralph Munn	I	23	1,450	120	1
Hawn Creek Res	R-2570	Yamhill	Hawn Creek	Hawn Cr. District Improvement Corp.	I	23	1,430	153	1
Buether Res.	R-1567	Sherman	Cottonwood Canyon	Paula Salomon	I	36	904	45	1
Piute Res	R-1330	Lake	Piute Creek	Warner Valley Stock Co.	I	40	798	1,051	1
Alder Creek	R-5844	Harney	Alder Creek	Lloyd Hill	I	55	575	640	1
Belchers Dam	R-3872	Multnomah	Middle Fork Beaver Creek	Darrell Belchers	I	28	1,120	30	1
Smyth's Creek Dam	R-1641	Harney	Smyth's Creek	D.H. Smyth	I	24	1,320	160	1
Johnson Creek Res.	R-1303	Crook	Johnson Creek	Claude Hudspeth	I	44	696	390	1
Yokom Res	R-904	Grant	Birch Creek	John F. Cawrse	I	25	1,224	45	1
M-C Res	R-8188	Lake	Foley Creek	DOI/BLM	SF	17	1,777	70	1
Sams Valley Res	R-3421	Jackson	E. Fk. Sams, W.Fk.Sams,&Minera	Sams Valley Irrigation Assoc.	I	60	500	890	1
Olalla Dam	R-5069	Lincoln	West Ollalla Creek	Georgia Pacific	O	83	355	3,650	1
Mt. Springs Ranch Dam	R-4840	Polk	Gooseneck Creek	Alice Propes	I	40	730	70	1
Little Squaw Flat	R-705	Klamath	Run-off	Circle 5 Ranch	IO	12	2,428	293	1
Ritter	R-11241	Klamath	Wildhorse Creek	Ritter Ranch	I	30	942	293	1
Star Mountain	R-6769	Malheur	No. Fork Granite Creek	Charles W. Chapman	I	66	420	940	1
Mainline 2	R-5534	Crook	Sarvis Creek	Art Smith/L.S. Ranch	I	36	766	36	1
Smith	R-3511	Klamath	Dobe, Pine, L.Pine, & Rat. Cre	Richard A. Smith	I	19	1,450	920	1
Jubilee Meadows	R-4874	Union	Mottet Creek	ODF&W	R	50	550	1,579	1
Charley Horse Reservoir	R-4138	Jackson	Iron Gulch Creek	Eldred Charley	RP	26	1,050	48	1
Somerville, The Res	R-44	Malheur	Spring Creek	Tom Davis Livestock Co.	I	30	900	2,000	1
Mortimer Canyon Dam	R-915	Harney	Mortimer Canyon Creek	Robert Smith	I	30	900	212	1
DeRaeve Res	R-6487	Polk	Ash Swale	Marvin DeRaeve	I	18	1,459	346	1
Spada Res.	R-4964	Marion	Champoeg Creek	A & R Spada	I	22	1,190	329	1
Balm Creek Reservoir	R-3679	Baker	Balm Cr. - Balm Cr. & Union Sp	Ralph Jacobs	I	65	400	2,926	1
Grier Res.	R-11244	Douglas	Hubbard Creek, Trib of	Bill Tipton	R	15	1,720	45	1
Whiteline Res	R-801	Klamath	Swan Lake, Trib to	Jeld-Wen Inc.	I	21	1,200	2,692	1
Stallard Dam	R-964	Harney	Otis Creek	Chester H. Stallard	I	35	718	193	1
Vaughn Log Pond	R-1041	Lane	Noti Creek	Long-Bell Lumber Co.	O	10	2,500	132	1
Selmac Lake	R-5552	Josephine	McMullen Creek	Josephine County	RIS	33	751	1,675	1

Table E-1b. OWRD Regulated Dams without Hydropower as Beneficial Use (Potential Power Generation Rate > 1 MW)

						Dam Height (ft)	Discharge Rating (cfs)	Storage Volume (ac-ft)	Surrogate Power Generation Rating Potential
DAM_NAME	STATE_ID	COUNTY	RIVER	OWNER_NAME	PURPOSES	DAM_HEIGHT	MAX_DISCHG	NORML_STOR	Megawatta
Pettit Res.	R-3247	Marion	Brush Creek	Dr. Virgil E. Pettit	OR	24	1,030	223	1
Bumphead Res	R-2162	Klamath	Lost River, Trib to	Willow Valley Irrigation District	I	25	988	1,450	1
Antelope (Malheur)	R-664	Malheur	Jack, Antelope, & Jordan Creek	Jordan Valley Irrigation District	I	56	440	55,000	1
Cherry Creek	R-7744	Jefferson	Cherry Creek	Joe Paulson	I	43	553	86	1
Anderson - Roy Res.	R-5326	Clackamas	Marquam Creek	Joseph F. Dobbes	R	25	950	28	1
Guano Canyon Dam	R-922	Harney	Guano Creek	Clarence S. Miller	I	19	1,249	580	1

Notes:
Purpose of Use Codes: I - irrigation, H - hydroelectric, C - flood control and storm water management, N - navigation, S - water supply, R - recreation, P - fire protection, stock, or small farm pond, D - debris control, T - tailings, O - other

Surrogate Power Generation Rating calculated by multiplying dam height (ft) X discharge rating (cfs) x 0.00008078 conversion factor X 50% efficiency

Table E-3. Summary Data and Calculations for Instream Demand Calculations for Administrative Basins

	WAB ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
Basin 1 - North Coast														
AINR50 (percent ratio from region)	Coastal Region	58%	57%	65%	83%	89%	91%	92%	96%	97%	97%	81%	59%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	18,861	17,797	14,233	8,885	4,808	2,801	1,525	973	1,015	1,993	11,258	19,065	
	Total Instream Demand (cfs)	10,859	10,168	9,262	7,353	4,260	2,541	1,397	931	982	1,939	9,137	11,337	
	Total Instream Demand (acre-feet)	667,696	564,682	569,496	437,545	261,911	151,201	85,892	57,273	58,424	119,245	543,669	697,055	4,214,090
	Existing Instream Water Rights at Basin Discharge Points (cfs)	3,152	3,152	3,150	3,044	2,355	1,173	893	670	681	2,026	3,087	3,318	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	193,809	175,053	193,686	181,142	144,785	69,813	54,892	41,186	40,529	124,568	183,689	204,016	1,607,169
Basin 2 - Willamette														
AINR50 (percent ratio from region)	Coastal Region	50%	49%	55%	58%	64%	71%	75%	81%	83%	89%	75%	51%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	51,411	49,496	42,687	36,584	28,407	15,861	8,006	5,545	5,754	8,408	24,455	53,093	
	Total Instream Demand (cfs)	25,671	24,148	23,436	21,248	18,287	11,250	6,019	4,481	4,783	7,458	18,230	27,125	
	Total Instream Demand (acre-feet)	1,578,434	1,341,092	1,441,044	1,264,336	1,124,398	669,445	370,086	275,531	284,594	458,561	1,084,731	1,667,827	11,560,078
	Existing Instream Water Rights at Basin Discharge Points (cfs)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	92,231	83,306	92,231	89,256	92,231	89,256	92,231	92,231	89,256	92,231	89,256	92,231	1,085,950
Basin 3 – Sandy														
AINR50 (percent ratio from region)	Coastal Region	50%	49%	55%	58%	64%	71%	75%	81%	83%	89%	75%	51%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	3,190	3,130	2,760	3,120	2,740	1,620	950	633	682	843	2,210	3,230	
	Total Instream Demand (cfs)	1,593	1,527	1,515	1,812	1,764	1,149	714	512	567	748	1,647	1,650	
	Total Instream Demand (acre-feet)	97,940	84,807	93,172	107,826	108,455	68,375	43,914	31,453	33,729	45,976	98,028	101,465	915,141
	Existing Instream Water Rights at Basin Discharge Points (cfs)	1,900	1,900	2,000	2,000	2,000	1,400	800	400	500	650	1,500	1,500	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	116,826	105,521	122,975	119,008	122,975	83,306	49,190	24,595	29,752	39,967	89,256	92,231	995,603
Basin 4 – Hood														
AINR50 (percent ratio from region)	Coastal Region	63%	55%	54%	55%	55%	59%	69%	75%	73%	78%	74%	68%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	638,833,731	2,038	2,336	2,163	2,074	1,976	1,431	907	668	617	693	1,314	

WAB ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
Total Instream Demand (cfs)	1,282	1,284	1,169	1,142	1,082	848	622	499	453	537	975	1,240	
Total Instream Demand (acre-feet)	78,832	71,326	71,894	67,951	66,542	50,455	38,220	30,663	26,969	33,046	58,039	76,235	670,171
Existing Instream Water Rights at Basin Discharge Points (cfs)	202	304	314	321	293	288	275	274	260	231	126	196	
Existing Instream Water Rights at Basin Discharge Points (acre-feet)	12,420	16,900	19,289	19,113	18,004	17,151	16,885	16,864	15,460	14,210	7,482	12,072	185,849

Basin 5 – Deschutes														
AINR50 (percent ratio from region)	Coastal Region	63%	55%	54%	55%	55%	59%	69%	75%	73%	78%	74%	68%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	5,830	6,980	7,440	8,180	7,460	6,600	5,190	4,780	4,800	4,940	5,050	5,480	
	Total Instream Demand (cfs)	3,668	3,838	4,021	4,505	4,085	3,912	3,555	3,567	3,525	3,831	3,748	3,702	
	Total Instream Demand (acre-feet)	225,508	213,154	247,258	268,058	251,182	232,767	218,612	219,305	209,729	235,554	223,018	227,628	2,771,772
	Existing Instream Water Rights at Basin Discharge Points (cfs)	4,500	4,500	4,500	4,000	4,000	4,000	4,000	3,500	3,800	3,800	3,800	4,500	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	276,694	249,917	276,694	238,017	245,950	238,017	245,950	215,207	226,116	233,653	226,116	276,694	2,949,025

Basin 6 - John Day														
AINR50 (percent ratio from region)	Coastal Region	63%	55%	54%	55%	55%	59%	69%	75%	73%	78%	74%	68%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	1,250	2,440	3,250	4,860	5,050	2,700	715	340	271	380	542	940	
	Total Instream Demand (cfs)	786	1,342	1,757	2,676	2,765	1,600	490	254	199	295	402	635	
	Total Instream Demand (acre-feet)	48,351	74,512	108,009	159,262	170,036	95,223	30,117	15,599	11,841	18,120	23,936	39,046	794,051
	Existing Instream Water Rights at Basin Discharge Points (cfs)	500	1,000	2,000	2,000	2,000	2,000	500	500	500	500	500	500	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	30,744	55,537	122,975	119,008	122,975	119,008	30,744	30,744	29,752	30,744	29,752	30,744	752,727

Basin 7 – Umatilla														
AINR50 (percent ratio from region)	Coastal Region	73%	70%	61%	48%	47%	56%	70%	77%	80%	82%	78%	75%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	1,913	1,752	2,284	2,331	1,689	714	351	268	295	316	455	881	
	Total Instream Demand (cfs)	775	1,225	1,383	1,128	788	399	245	206	236	258	353	658	
	Total Instream Demand (acre-feet)	47,655	68,018	85,048	67,116	48,449	23,721	15,082	12,661	14,057	15,871	21,006	40,480	459,162
	Existing Instream Water Rights at Basin Discharge Points (cfs)	294	303	313	336	314	289	152	116	281	332	335	287	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	18,077	16,828	19,246	19,993	19,307	17,197	9,346	7,133	16,721	20,414	19,934	17,647	201,842

	WAB ID	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
Basin 8 - Grande Ronde														
AINR50 (percent ratio from region)	Coastal Region	73%	70%	61%	48%	47%	56%	70%	77%	80%	82%	78%	75%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	1,913	3,031	4,179	7,149	9,120	7,916	2,781	1,317	1,171	1,105	1,337	1,678	
	Total Instream Demand (cfs)	1,392	2,119	2,531	3,459	4,255	4,418	1,942	1,010	937	902	1,038	1,253	
	Total Instream Demand (acre-feet)	85,570	117,696	155,619	205,802	261,602	262,903	119,431	62,107	55,753	55,487	61,753	77,069	1,520,793
	Existing Instream Water Rights at Basin Discharge Points (cfs)	857	870	2,120	5,120	5,060	5,017	1,505	802	802	803	1,208	826	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	52,707	48,317	130,354	304,661	311,152	298,550	92,567	49,298	47,703	49,398	71,893	50,813	1,507,413

Basin 9 – Powder														
AINR50 (percent ratio from region)	Coastal Region	73%	70%	61%	48%	47%	56%	70%	77%	80%	82%	78%	75%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	622	985	1,724	3,055	3,881	3,183	925	452	349	352	438	535	
	Total Instream Demand (cfs)	453	689	1,044	1,478	1,811	1,777	646	347	279	288	340	400	
	Total Instream Demand (acre-feet)	27,831	38,245	64,185	87,942	111,327	105,712	39,725	21,336	16,619	17,687	20,225	24,587	575,420
	Existing Instream Water Rights at Basin Discharge Points (cfs)	85	120	150	150	150	150	85	85	85	85	85	85	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	5,226	6,664	9,223	8,926	9,223	8,926	5,226	5,226	5,058	5,226	5,058	5,226	79,210

Basin 10 – Malheur & 11 - Owyheee														
AINR50 (percent ratio from region)	Coastal Region	73%	70%	61%	48%	47%	56%	70%	77%	80%	82%	78%	75%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	257	632	1,109	1,394	852	507	196	120	110	143	181	205	
	Total Instream Demand (cfs)	187	442	672	674	397	283	137	92	88	117	140	153	
	Total Instream Demand (acre-feet)	11,519	24,540	41,306	40,118	24,424	16,854	8,399	5,672	5,240	7,187	8,344	9,399	203,003
	Existing Instream Water Rights at Basin Discharge Points (cfs)	0	0	0	0	0	0	0	0	0	0	0	0	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	0	0	0	0	0	0	0	0	0	0	0	0	0

Basin 12 - Malheur Lake														
AINR50 (percent ratio from region)	Coastal Region	73%	70%	61%	48%	47%	56%	70%	77%	80%	82%	78%	75%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	271	458	953	1,669	1,392	787	257	148	138	156	179	226	
	Total Instream Demand (cfs)	197	320	577	807	649	439	180	113	110	127	139	169	
	Total Instream Demand (acre-feet)	12,139	17,797	35,492	48,035	39,920	26,143	11,051	6,976	6,544	7,819	8,250	10,364	230,530
	Existing Instream Water Rights at Basin Discharge Points (cfs)	15	21	37	77	84	43	18	13	12	13	13	15	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	943	1,175	2,287	4,570	5,190	2,552	1,091	774	716	821	799	893	21,810

Basin 13 – Goose & Summer Lake														
AINR50 (percent ratio from region)	Coastal Region	73%	70%	61%	48%	47%	56%	70%	77%	80%	82%	78%	75%	
	50% Exceedance Flow – Total Basin Discharge (cfs)	276	445	1,006	1,675	1,966	917	225	120	124	135	169	221	
	Total Instream Demand (cfs)	201	311	609	810	917	512	157	92	100	110	131	165	
	Total Instream Demand (acre-feet)	12,343	17,260	37,460	48,210	56,402	30,454	9,650	5,637	5,922	6,773	7,788	10,159	248,056
	Existing Instream Water Rights at Basin Discharge Points (cfs)	20	41	94	160	114	35	6	5	10	3	3	12	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	1,230	2,277	5,780	9,521	7,010	2,100	395	295	613	184	179	738	30,321

Basin 14 – Klamath														
AINR50 (percent ratio from region)	Coastal Region	63%	55%	54%	55%	55%	59%	69%	75%	73%	78%	74%	68%	
	50% Exceedance Flow – Total Basin Discharge (cfs)	2,325	2,559	3,274	3,842	3,470	2,898	1,961	1,379	1,207	1,312	1,580	1,932	
	Total Instream Demand (cfs)	1,462	1,407	1,769	2,116	1,900	1,718	1,343	1,029	886	1,017	1,173	1,305	
	Total Instream Demand (acre-feet)	89,915	78,155	108,792	125,888	116,831	102,214	82,595	63,246	52,726	62,555	69,778	80,240	1,032,934
	Existing Instream Water Rights at Basin Discharge Points (cfs)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,330	1,160	1,260	1,500	1,500	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	92,231	83,306	92,231	89,256	92,231	89,256	92,231	81,779	69,025	77,474	89,256	92,231	1,040,509

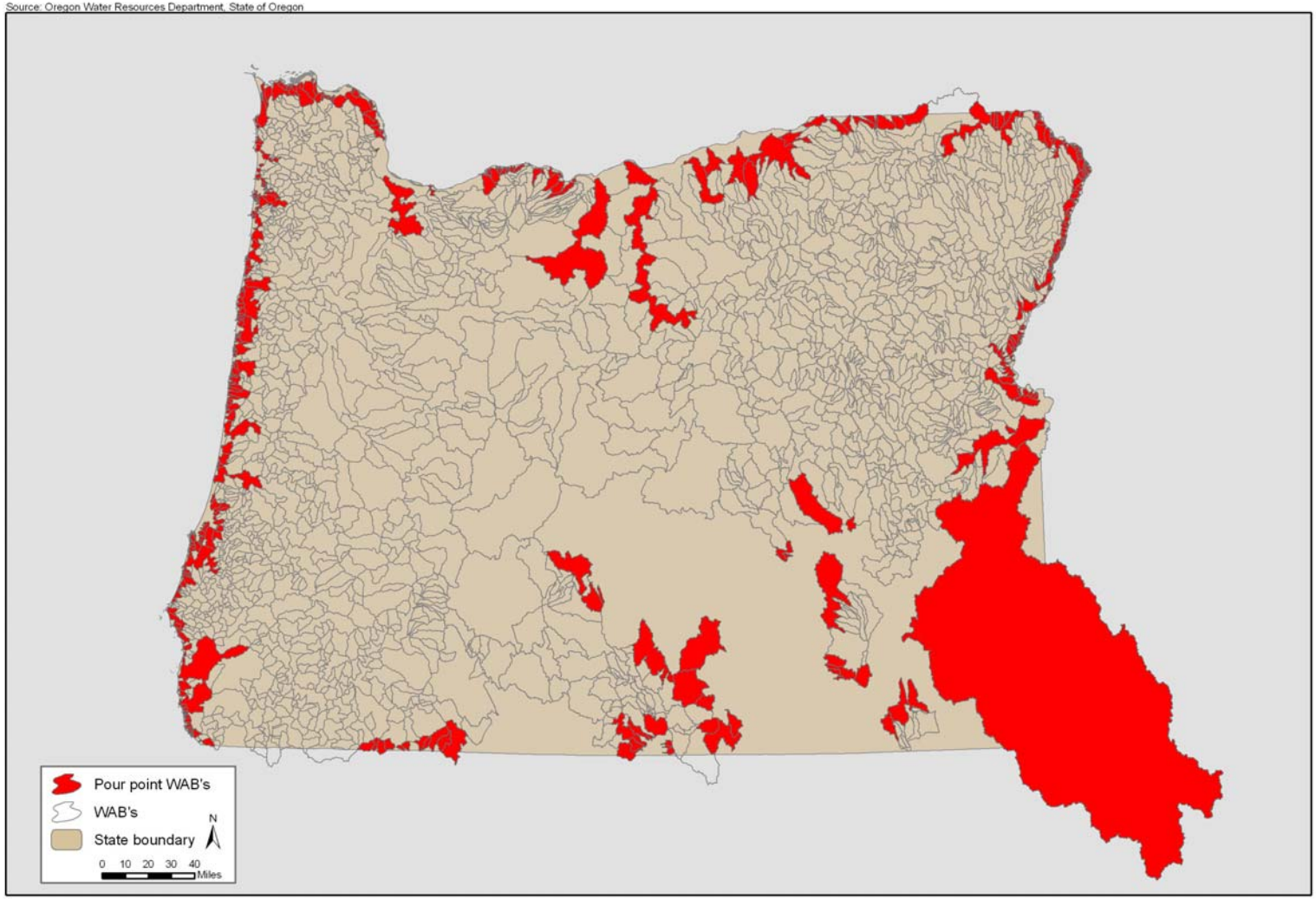
Basin 15 – Rogue														
AINR50 (percent ratio from region)	Coastal Region	50%	49%	55%	58%	64%	71%	75%	81%	83%	89%	75%	51%	
	50% Exceedance Flow – Total Basin Discharge (cfs)	13,100	16,900	13,900	11,700	8,190	4,890	2,690	1,980	1,930	2,420	5,040	12,300	
	Total Instream Demand (cfs)	6,541	8,245	7,631	6,795	5,272	3,469	2,022	1,600	1,604	2,147	3,757	6,284	
	Total Instream Demand (acre-feet)	402,200	457,905	469,237	404,346	324,179	206,391	124,345	98,383	95,451	131,984	223,558	386,382	3,324,360
	Existing Instream Water Rights at Basin Discharge Points (cfs)	3,500	3,500	3,500	3,500	3,000	2,700	2,000	2,400	2,400	1,600	3,500	3,500	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	215,207	194,380	215,207	208,264	184,463	160,661	122,975	147,570	142,810	98,380	208,264	215,207	2,113,388

Basin 16 – Umpqua														
AINR50 (percent ratio from region)	Coastal Region	50%	49%	55%	58%	64%	71%	75%	81%	83%	89%	75%	51%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	14,400	15,000	13,500	10,400	6,990	3,590	1,860	1,340	1,290	1,690	5,110	13,900	
	Total Instream Demand (cfs)	7,190	7,318	7,412	6,040	4,500	2,546	1,398	1,083	1,072	1,499	3,809	7,101	
	Total Instream Demand (acre-feet)	442,113	406,424	455,734	359,419	276,680	151,522	85,978	66,582	63,799	92,170	226,663	436,643	3,063,728
	Existing Instream Water Rights at Basin Discharge Points (cfs)	1,000	1,000	1,000	1,000	1,000	1,000	750	750	750	1,000	1,000	1,000	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	61,488	55,537	61,488	59,504	61,488	59,504	46,116	46,116	44,628	61,488	59,504	61,488	678,347

Basin 17 - South Coast														
AINR50 (percent ratio from region)	Coastal Region	58%	57%	65%	83%	89%	91%	92%	96%	97%	97%	81%	59%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	18,518	19,708	16,843	9,486	4,283	2,345	1,220	680	548	985	8,653	19,055	
	Total Instream Demand (cfs)	10,661	11,259	10,960	7,851	3,794	2,127	1,118	652	530	958	7,023	11,331	
	Total Instream Demand (acre-feet)	655,547	625,308	673,930	467,144	233,297	126,558	68,745	40,064	31,515	58,900	417,890	696,707	4,095,605
	Existing Instream Water Rights at Basin Discharge Points (cfs)	3,523	3,536	3,354	3,207	2,419	1,460	776	542	438	1,762	2,950	3,473	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	216,639	196,363	206,234	190,853	148,753	86,887	47,700	33,334	26,063	108,333	175,512	213,570	1,650,243

Basin 18 - Mid Coast														
AINR50 (percent ratio from region)	Coastal Region	58%	57%	65%	83%	89%	91%	92%	96%	97%	97%	81%	59%	
	50% Exceedance Flow - Total Basin Discharge (cfs)	736,484	651,189	642,027	516,711	320,576	188,972	115,742	84,171	82,212	162,340	542,738	767,480	
	Total Instream Demand (cfs)	10,112	9,819	8,668	7,049	4,027	2,325	1,328	884	875	1,464	7,284	10,455	
	Total Instream Demand (acre-feet)	621,767	545,300	532,997	419,460	247,614	138,356	81,676	54,344	52,060	90,048	433,429	642,877	3,859,928
	Existing Instream Water Rights at Basin Discharge Points (cfs)	1,371	1,371	1,371	1,328	1,014	744	493	441	461	1,092	1,513	1,521	
	Existing Instream Water Rights at Basin Discharge Points (acre-feet)	84,300	76,141	84,300	79,027	62,361	44,241	30,301	27,138	27,450	67,138	90,024	93,523	765,944

Source: Oregon Water Resources Department, State of Oregon



Pour Point Water Availability Basins
FIGURE E-1

HDR
ONE COMPANY | *Many Solutions*

This page left intentionally blank.

APPENDIX F

Uncertainty Analysis Workbook

OWRD Statewide/Regional Demand Forecast

Uncertainty Development Workbook

September 9, 2008

Table of Contents

Introduction F-1
Base Case F-2
Climate Change F-10
Conservation.....F-14

Introduction

The HDR Modeling Team used this workbook to establish parameters for the uncertainty analysis and scenario analysis carried out in developing the demand forecast. The workbook documents which variables were adjusted in these analyses. It explains issues the Modeling Team considered in carrying out the uncertainty analysis. Finally, it provides the specific values used, and the probability distributions used in the Monte Carlo simulation procedure.

For each variable considered in the uncertainty analysis, the modeling team defined a probability distribution for use in the Monte Carlo simulation procedure. This allows the variable to take on a range of different values within a defined range, reflecting uncertainty in existing or future conditions. These distributions are essentially bell-shaped curves, in which some values occur much more frequently than others, based on the probability they will occur. The HDR Modeling Team defined the particular distributions used in this workbook, based on their judgment regarding the range of possible values that might occur, either currently or in the future.

The graphic at the bottom of each page in this workbook illustrates the values used in the Monte Carlo simulation. For most of the variables, the 10th, 50th, and 90th percentile values were assigned in the probability distributions (some use 5%, 50% and 95% instead). Where these graphics refer to “the given value,” this refers to the value of that variable used in the deterministic forecasting model (“spreadsheet tool”). For some variables, the probability distribution was held constant over time. For others, the distributions take on different values over time to model time-dependent trends.

The Modeling Team recognizes that the data acquired for the demand forecast has many limitations, and also that predicting future conditions is inherently uncertain. We encourage OWRD and other users of the forecasting model to review the information in this workbook and consider carefully how the factors listed may affect the forecasting results. Other assumptions for both the base case and future scenarios may be perfectly plausible. This workbook can be used by others to provide a structured thought process for generating alternative sets of assumptions.

Scenario: Base Case

Water Use Category: Municipal and Domestic

Affected Variable: Population Numbers for Initial Year (2007)

Drivers:

- The population estimate for the initial year is based on data from the 2000 U.S. Census, adjusted to 2007 based on data from Portland State University's 2007 Oregon Population Report. The actual 2007 population in any given census block could be lower or higher than estimated using this method.
- The population estimates from both the Census and PSU provide only one number, rather than a range of values.
- The modeling team built uncertainty around those numbers based on professional judgment.

Affected Sector or Group:

- Municipal/Domestic

Uncertainty Parameters:

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
2007: 95% of the given value for 2007 population.	**2007:** 100% of the given value for 2007 population.	**2007:** 105% of the given value for 2007 population.

Scenario: Base Case

Water Use Category: Municipal and Domestic

Affected Variable: Annual Population Growth Rate

Drivers:

- Population growth rates from 2007 to 2050 were obtained from Oregon State's Office of Economic Analysis (OEA). This source provided only one growth rate for a given geography and time period, rather than a range of values.
- Actual growth may occur at slower or faster rates than the number forecasted.
- Uncertainty is greater in the later years because underlying conditions that drive growth may change from current conditions.

Affected Sector or Group:

- Municipal/Domestic

Uncertainty Parameters:

Note: The modeling team assumes uncertainty will be slightly greater on the high end, and the uncertainty distribution reflects this assumption.

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
2010: 90% of the given annual growth rate. For example, if the given value is a 1.0% annual growth rate, the low number would be 0.9%. **2050:** 50% of the given annual growth rate. For example, if the given value is a 1.0% annual growth rate, the low number would be 0.5%. Straight-line interpolation of uncertainty between 2010 and 2050.	**2010 & 2050:** 100% of the given value for annual growth rate. For example, if the given value is a 1.0% annual growth rate, the medium number would be 1.0%.	**2010:** 115% of the given annual growth rate. For example, if the given value is a 1.0% annual growth rate, the high number would be 1.15%. **2050:** 200% of the given annual growth rate. For example, if the given value is a 1.0% annual growth rate, the high number would be 2.0%. Straight-line interpolation of uncertainty between 2010 and 2050.

Scenario: Base Case

Water Use Category: Municipal and Domestic

Affected Variable: Total Per Capita Use

Drivers:

- Within each climate zone, data from a small number of water systems was used to estimate a per capita water use for all water systems classified in the same system category within that zone. In the first generation forecast, the number of systems used to construct the average was from one to three systems. The actual average water use per capita may be different from the average calculated using this relatively small data set.
- The representative per capita demands used to construct the averages depend on data self-reported by utilities. There may be errors in that data.
- The per capita demands are intentionally held constant over time in the base case. Code savings (along with programmatic conservation) are incorporated in the conservation scenario. Even without code savings and conservation actions, there could be trends in per capita water use that are not captured by this approach.

Affected Sector or Group:

- Municipal/Domestic

Uncertainty Parameters:

Note: The modeling team assumes uncertainty will be greater on the high end, and the uncertainty distribution reflects this assumption. This is justified, in part, by the mathematics of per capita water use, which is constrained by zero on the low end, but has no such constraint on the high end.

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
All Years: 75% of the given total per capita demand. For example, if the given value is 100 gallons per day (gpd), then 75 gpd will be used.	**All Years:** 100% of the given total per capita demand. For example, if the given value is 100 (gpd), then 100 gpd will be used.	**All Years:** 150% of the given total per capita demand. For example, if the given value is 100 (gpd), then 150 gpd will be used.

Scenario: Base Case

Water Use Category: Industrial

Affected Variable: Industrial Water Use by County

Drivers:

- The industrial category is self-supplied users with commercial or industrial uses (not receiving water from a municipal system) The demand is estimated based on OWRD data on stand-alone commercial and industrial water rights, using a standard set of assumptions regarding how much of the industrial water rights are actually being used. The assumptions are that 50% of the instantaneous water rights were used for two 8-hour shifts per day; for 7 days a week, all 52 weeks each year. This is essentially a "placeholder" for this category of demand, pending further research and/or outreach to industrial water users.
- Actual demand for the initial year may vary considerably from the estimated values.
- Over time, the set of water users in this category may change.

Affected Sector or Group:

- Industrial Water

Uncertainty Parameters:

Note: The modeling team assumes uncertainty will be greater on the low end and the uncertainty distribution reflects this assumption. This is because the total water right authorized serves as a legal limit and it is assumed most industrial users have installed physical capacity with this limit in mind.

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
2010: 50% of the given value for industrial demand. For example, if the given value is 50,000 gallons, then 25,000 gallons will be used. **2050:** 25% of the given value for industrial demand.	**2010 & 2050:** 100% of the given value for industrial demand. For example if the given value is 50,000 gallons, then 50,000 acre feet will be used.	**2010:** 125% of the given value for industrial demand. For example, if the given value is 50,000 gallons, then 62,500 gallons will be used. **2050:** 150% of the given value for industrial demand.

Scenario: Base Case

Water Use Category: Agricultural

Affected Variable: Crop Acreage – Total

Drivers:

- USGS data used was not checked for accuracy or method. Previous USGS agricultural censuses have been relatively consistent (within 10-20%), but data were not completely evaluated.
- Annual variation in total acreage of crops irrigated may be significant, based on weather and market conditions for agricultural commodities.
- Regulatory constraints are a factor in terms of maximum amounts of land and water available for irrigation.

Affected Sector or Group:

- Agricultural

Uncertainty Parameters:
Note: Because total irrigable acreage is limited, the uncertainty distribution is intentionally weighted toward the low end.

For crop acreage, the "given value" from the Forecasting Model (spreadsheet tool) remained constant in all years. This is different from the Reference Forecast, where the crop acreage was modeled to vary over time, within each county (with a net upward trend in acreage).

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
2010: 85% of the given value. **2050:** 65% of the given value. Straight-line interpolation from 2010 through 2050	The given value will be used for crop acreage.	**2010:** 110% of the given value. **2050:** 130% of the given value. Straight-line interpolation from 2010 through 2050.

Scenario: Base Case

Water Use Category: Agricultural

Affected Variable: Crop Water Requirement (Total Use)

Drivers:

- Values represent average year irrigation requirement. Crops may require more or less water than estimated. Crops typically require 20-70% more in hot, dry years.
- Low water use crops tend to need more (on a percentage basis) in hot, dry years.
- USGS data used was not checked for accuracy or method.
- High and low uncertainties are estimates based on typical crops in the Oregon Irrigation Guide. The Guide includes information on irrigation requirements for various frequencies up to 1 year in 20.

Affected Sector or Group:

- Agricultural

Uncertainty Parameters:

Low (10% or less)	**Medium** (50% or mean)	**High** (95% or more)
75% of the given value If use is estimated at 2.0 feet per year, the value used will be 1.5 feet	100% of the given value for crop water requirement.	135% of the given value. If use is estimated at 2.0 feet per year, the value used will be 2.7 feet

Scenario: Base Case

Water Use Category: Agricultural

Affected Variable: Irrigation Efficiency

Drivers:

- USGS data were not checked for accuracy or methods.
- Individual and county-wide irrigation systems may be more or less efficient than estimated.
- Highest irrigation efficiencies are for drip systems, from 80 to 90%.
- Moderate irrigation efficiencies are for sprinklers, from 70 to 85%.
- Lower irrigation efficiencies for gravity or flood, from 50 to 70%.
- Better system management, field leveling, and other changes can improve efficiencies.

Affected Sector or Group:

- Agricultural

Uncertainty Parameters:

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
75% of the given value. For example, if the efficiency is listed as 0.5, 10% then 0.375 will be used.	100% of the given value for irrigation efficiency. For example, if efficiency is given as 70%, then 70% will be used.	125% of the given value. For example, if the efficiency is listed as 0.5, then 0.625 will be used.

Scenario: Base Case

Water Use Category: Agricultural

Affected Variable: Conveyance Efficiency

Drivers:

- The 80% efficiency value assumed throughout the calculations is essentially a placeholder estimate based on professional judgment. It could be improved by a true survey or study of conveyance efficiency throughout the state.
- County-wide estimates represent a combination of many separate systems, including surface and groundwater.
- Some individual systems (particularly groundwater) may approach 100% efficiency (fully piped, with little waste).
- Some individual systems may be less than 40 to 50% efficient (long, unlined canals through loose soils).

Affected Sector or Group:

- Agricultural

Uncertainty Parameters:

Note: the uncertainty is intentionally weighted towards the low end, since 100% is the absolute limit on the high end and the estimated value of 80% is already fairly close to that limit.

For conveyance efficiency, a lower value means more water will be needed. A higher value means less water will be needed.

Low (5% or less)	**Medium** (50% or mean)	**High** (95% or more)
A value of 60% will be used for conveyance efficiency.	The median conveyance efficiency is estimated to be 80%.	A value of 90% will be used for conveyance efficiency.

Scenario: Climate Change

Water Use Category: Municipal and Domestic

Affected Variable: Per Capita Use – Outdoor

Drivers:

- For this scenario, it was assumed that increased temperatures and longer seasonal dry periods may increase outdoor water use in the municipal and domestic sectors.
- On the other hand, increased precipitation during irrigation season could have a countervailing effect and decrease the irrigation requirement.
- Results from two global circulation model studies were used: Parallel Climate Model (PCM) from the National Center for Atmospheric Research and the Hadley model (Scenario HadCM2). These are documented in *The Impact of Climate Change on Regional Systems,* edited by J.B Smith and R. Mendelsohn, published by Edward Elgar, Northampton, MA, 2006.
- Results from the two models were used as follows:
    - West of Cascades: The studies predicted increased water requirements ranging from 11% (PCM) to 26% (HadCM2). For this scenario, an average of these two values (18%) was used as the median value. At the 90% probability level, the higher value (26%) was used. At the 10% probability level, a decrease of 10% irrigation requirement was used, reflecting the possibility of increased precipitation during the growing season.
    - Mountains and high plateaus: The studies predicted increased water requirements ranging from 1% (HadCM2) to 15% (PCM). An average of these two values (8%) was used as the median value. At the 90% probability level the higher end of the range (15%) was used. At the 10% probability level, a decrease of 10% irrigation requirement was used, reflecting the possibility of increased precipitation during the growing season.
    - Eastern Oregon and low desert: The studies predicted increased water requirements ranging from 6% (PCM) to 17% (HadCM2) increase. For this scenario, an average of these two values (12%) was used as the median value. At the 90% probability level the higher end of the range (17%) was used. At the 10% probability level, a decrease of 10% irrigation requirement was used, reflecting the possibility of increased precipitation during the growing season.
- Note these assumptions parallel those used for the Agricultural water use category.

Affected Sector or Group: Municipal/Domestic

Uncertainty Parameters:
Note: The modeling team assumes uncertainty will be slightly greater on the high end, and the uncertainty distribution reflects this assumption.

Values are adjusted from 2010 to 2050, following a straight-line trend.

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
Mountains and High Plateaus **2010:** 100% of the given outdoor per capita demand. **2050:** 90% of the given outdoor per capita demand.	**Mountains and High Plateaus** **2010:** 100% of the given outdoor per capita demand. **2050:** 108% of the given outdoor per capita demand.	**Mountains and High Plateaus** **2010:** 100% of the given outdoor per capita demand. **2050:** 115% of the given outdoor per capita demand.
West of Cascades **2010:** 100% of the given outdoor per capita demand. **2050:** 90% of the given outdoor per capita demand.	**West of Cascades** **2010:** 100% of the given outdoor per capita demand. **2050:** 118% of the given outdoor per capita demand.	**West of Cascades** **2010:** 100% of the given outdoor per capita demand. **2050:** 126% of the given outdoor per capita demand.
Eastside/Low Desert **2010:** 100% of the given outdoor per capita demand. **2050:** 90% of the given outdoor per capita demand.	**Eastside/Low Desert** **2010:** 100% of the given outdoor per capita demand. **2050:** 112% of the given outdoor per capita demand.	**Eastside/Low Desert** **2010:** 100% of the given outdoor per capita demand. **2050:** 117% of the given outdoor per capita demand.

Scenario: Climate Change

Water Use Category: Agricultural

Affected Variable: Irrigation Requirement

Drivers:

- For this scenario it was assumed that increased temperatures and longer seasonal dry periods may increase the irrigation requirement in the agricultural category.
- On the other hand, increased precipitation during the irrigation season could have a countervailing effect and decrease the irrigation requirement.
- Results from two global circulation model studies were used: Parallel Climate Model (PCM) from the National Center for Atmospheric Research and the Hadley model (Scenario HadCM2). These are documented in *The Impact of Climate Change on Regional Systems*, edited by J.B Smith and R. Mendelsohn, published by Edward Elgar, Northampton, MA, 2006.
- Results from the two models were used as follows:
    - West of Cascades: The studies predicted increased water requirements ranging from 11% (PCM) to 26% (HadCM2). For this scenario, an average of these two values (18%) was used as the median value. At the 90% probability level, the higher value (26%) was used. At the 10% probability level, a decrease of 10% irrigation requirement was used, reflecting the possibility of increased precipitation during the growing season.
    - Mountains and high plateaus: The studies predicted increased water requirements ranging from 1% (HadCM2) to 15% (PCM). An average of these two values (8%) was used as the median value. At the 90% probability level the higher end of the range (15%) was used. At the 10% probability level, a decrease of 10% irrigation requirement was used, reflecting the possibility of increased precipitation during the growing season.
    - Eastern Oregon and low desert: The studies predicted increased water requirements ranging from 6% (PCM) to 17% (HadCM2) increase. For this scenario, an average of these two values (12%) was used as the median value. At the 90% probability level the higher end of the range (17%) was used. At the 10% probability level, a decrease of 10% irrigation requirement was used, reflecting the possibility of increased precipitation during the growing season.
- Note these assumptions parallel those used in the Municipal water use category.
- **Affected Sector or Group:** Agricultural

Uncertainty Parameters:

Note: The modeling team assumes uncertainty will be slightly greater on the high end, and the uncertainty distribution reflects this assumption.

Values are adjusted from 2010 to 2050, following a straight-line trend.

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
Mountains and High Plateaus **2010:** 100% of the given crop irrigation requirement. **2050:** 90% of the given crop irrigation requirement.	**Mountains and High Plateaus** **2010:** 100% of the crop irrigation requirement. **2050:** 108% of the given crop irrigation requirement.	**Mountains and High Plateaus** **2010:** 100% of the given crop irrigation requirement. **2050:** 115% of the given crop irrigation requirement.
West of Cascades **2010:** 100% of the given crop irrigation requirement. **2050:** 90% of the given crop irrigation requirement.	**West of Cascades** **2010:** 100% of the given crop irrigation requirement. **2050:** 118% of the given crop irrigation requirement.	**West of Cascades** **2010:** 100% of the given crop irrigation requirement. **2050:** 126% of the given crop irrigation requirement.
Eastside/Low Desert **2010:** 100% of the given crop irrigation requirement. **2050:** 90% of the given crop irrigation requirement.	**Eastside/Low Desert** **2010:** 100% of the given crop irrigation requirement. **2050:** 112% of the given crop irrigation requirement.	**Eastside/Low Desert** **2010:** 100% of the given crop irrigation requirement. **2050:** 117% of the given crop irrigation requirement.

Scenario: Conservation

Water Use Category: Municipal and Domestic Use

Affected Variable: Per Capita Use – Total

Drivers:

- This scenario is intended to explore a range of conservation savings that may occur in future years. It represents savings from the plumbing code, programmatic conservation programs implemented by utilities, and rate changes designed to promote conservation.
- Because total water use is the affected variable, it encompasses both indoor and outdoor water savings from conservation.
- On the high end this scenario applies water savings that are more aggressive than what have typically been implemented by water utilities in the past decade. Substantial changes in public behavior plus significant investments would be required to achieve savings at the high end of the probability distribution shown below.
- This scenario assumes the necessary financial and/or political commitments will be available. For example, utilities will: 1) have funding available for hardware retrofits, 2) increase and/or restructure rates to motivate conservation, or 3) support mandatory conservation measures via codes or other regulatory means.
- It is assumed the conservation savings will be fully achieved by year 2030; therefore, per capita water use is held constant after 2030.
- Uncertainty is greater in the later years approaching 2030.

Affected Sector or Group:

- Municipal/Domestic

Uncertainty Parameters:

Note: The modeling team assumes uncertainty will be greater on the high end, and the uncertainty distribution reflects this assumption.

Straight-line interpolation of uncertainty between 2010 and 2030. Values are held constant after 2030.

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
2010: : 97% of the given value. For example, if the given value is 100 gallons per day (gpd), then 97 gpd will be used. **2030:** 70% of the given value. For example, if the given value is 100 gallons per day (gpd), then 70 gpd will be used.	**2010:** 100% of the given value. For example, if the given value is 100 gallons per day (gpd), then 100 gpd will be used. **2030:** 90% of the given value. For example, if the given value is 100 gallons per day (gpd), then 90 gpd will be used.	**2010** 103% of the given value. For example, if the given value is 100 gpd, then 103 gpd will be used. **2030:** 95% of the given value. For example, if the given value is 100 (gpd), then 95 gpd will be used.

Scenario: Conservation

Water Use Category: Industrial Use

Affected Variable: Industrial Water Use by County

Drivers:

- Water use in this category can be expected to become more efficient due to improvements in technology; investment in new facilities and reinvestment in existing facilities in an environment where water is scarce and factories need to be more efficient.
- It is assumed it will take until 2050 to fully achieve the conservation improvements in this category.

Affected Sector or Group:

- Industrial Water

Uncertainty Parameters:

Note: The modeling team assumes there is considerable opportunity for improvements in water – use efficiency in this category so the uncertainty will be greater on the low end. The uncertainty distribution reflects this assumption.

Straight line interpolation of values was used between 2010 and 2050.

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
2010: 50% of the given demand. **2050:** 25% of the given demand.	**2010:** 100% of the given demand. **2050:** 90% of the given demand.	**2010:** 103% of the given demand. **2050:** 100% of the given demand.

Scenario: Conservation

Water Use Category: Agricultural

Affected Variable: Irrigation Efficiency

Drivers:

- Increasing competition for water and continued attention to environmental goals are assumed likely to drive irrigators toward efficiency improvements.
- It is assumed increased use of efficient sprinklers and drip irrigation systems will reduce water use compared with the base case.
- Improved water supply management can also reduce water losses.
- Actual efficiency improvements will depend on economic forces (funding available, cost of water, etc.).
- It is assumed it will take until 2040 to fully achieve the conservation improvements in this category.

Affected Sector or Group:

- Agricultural

Uncertainty Parameters:

Note: increased efficiency means less water used.
Straight line interpolation of values from 2010 to 2040. Values held constant after 2040.

Low (10% or less)	**Medium** (50% or mean)	**High** (90% or more)
2010: 100% of the given value for irrigation efficiency. **2040**: 100% of the given value for irrigation efficiency (i.e. no change in efficiency over time).	**2010**: 100% of the given value for irrigation efficiency. **2040**: 115% of the given value for irrigation efficiency. If current efficiency is 50%, future efficiency would be 57.5%.	**2010**: 100% of the given value for irrigation efficiency. **2040**: 125% of the given value for irrigation efficiency. If current efficiency is 50%, future efficiency would be 62.5%.

Scenario: Conservation

Water Use Category: Agricultural

Affected Variable: Conveyance Efficiency

Drivers:

- Replacement of canals with pipelines and lining of canals reduces seepage and evaporation losses.
- Improved system management reduces waste.
- However, piping projects are expensive and typically depend on outside funding and this affects the probability they will be accomplished.

Affected Sector or Group:

- Agricultural

Uncertainty Parameters:

Note: increased efficiency means less water used.
Straight line interpolation of values from 2010 to 2040. Values held constant after 2040.

Low (10% or less)	**Medium** (50% or mean)	**High** (95% or more)
2010: 100% of the given value for conveyance efficiency. **2040**: 100% of the given value for conveyance efficiency (i.e. no change in efficiency over time).	**2010**: 100% of the given value for conveyance efficiency. **2040**: 105% of the given value for conveyance efficiency. If current efficiency is 80%, future efficiency would be 84%.	**2010**: 100% of the given value for conveyance efficiency. **2040**: 110% of the given value for conveyance efficiency. If current efficiency is 80%, future efficiency would be 88%.

Figures Illustrating Range of Values for Variables in Uncertainty Analysis

Figure F-1 shows the range of statewide population used as input for the municipal and domestic well sectors in the uncertainty analysis. This range indicates the "80% probability" that the population will fall within this range according to the uncertainty parameter assumptions for the initial year population and annual growth rate. Figure F-2 is a representative graph illustrating the range of uncertainty for per capita water demand for each month for Deschutes County in 2010. Similarly, the whisker markers (i.e. line showing the high and low range in the graph) indicate the 80% probability that the per capita water demand falls within the range shown for each month. Both of these figures show that the uncertainty range increases through the planning period because the values around the input variables also increases.

Figure F-3 shows the mean crop acreage input for the agricultural sector resulting from the uncertainty analysis, as well as the acreage associated with the 10% and 90% not-to-exceed probability values. Because it was assumed the mean crop acreage does not change through 2050, the mean value does not change; however, the range of uncertainty was allowed to increase over time. The plotted curves indicate the 80% probability that the acreage will fall within this range according to the uncertainty parameter assumptions, For example, in 2050 there is a 80% probability that the total irrigated acreage in Deschutes County will fall within approximately 38,000 acres and 58,000 acres.

Figure F-4 is a representative graph illustrating the range of uncertainty for crop irrigation requirement for Alfalfa in Baker County for each month. The graph shows the mean, 10% and 90% not-to-exceed probability values for crop irrigation requirement. Similarly, the whisker markers indicate the 80% probability that the crop irrigation requirement falls within the range shown for each month. At the peak demand in July, the uncertainty assumptions indicate that alfalfa would require anywhere from 7.0 to 12.1 inches. Figure F-4 also illustrates the difference between irrigation requirement for the base case and climate change scenarios. The difference in mean irrigation requirement for alfalfa is 0.2 inches in July. This range is relatively small is partially due to the wide range uncertainty in irrigation requirement defined for the base case. While the mean irrigation requirement under the climate change scenario was assumed to be higher, the modeling team made the distribution "tighter." Both of these factors resulted in a relatively small difference between the irrigation requirements between the base case and climate change scenario for agriculture.

The mean values for irrigation efficiency and conveyance efficiency were not assumed to change over time for the base case scenario; however, a range of uncertainty was defined for the two variables. The results of the uncertainty analysis show that there is a 80% probability that irrigation efficiency generally lies between 58% and 97%, while conveyance efficiency generally lies between 63% and 88%. Figure F-5 and Figure F-6 are representative graphs illustrating the range of uncertainty for irrigation efficiency and conveyance efficiency for Deschutes County. Figure F-5 and Figure F-6 also illustrate the difference between the irrigation and conveyance efficiencies for the base case and conservation scenarios. In general, the mean irrigation efficiency and conveyance efficiency for the conservation scenario is 10% and 8% improved over the base case, respectively.

This page left intentionally blank.

Figure F-1. Range of Statewide Total Population from Uncertainty Analysis

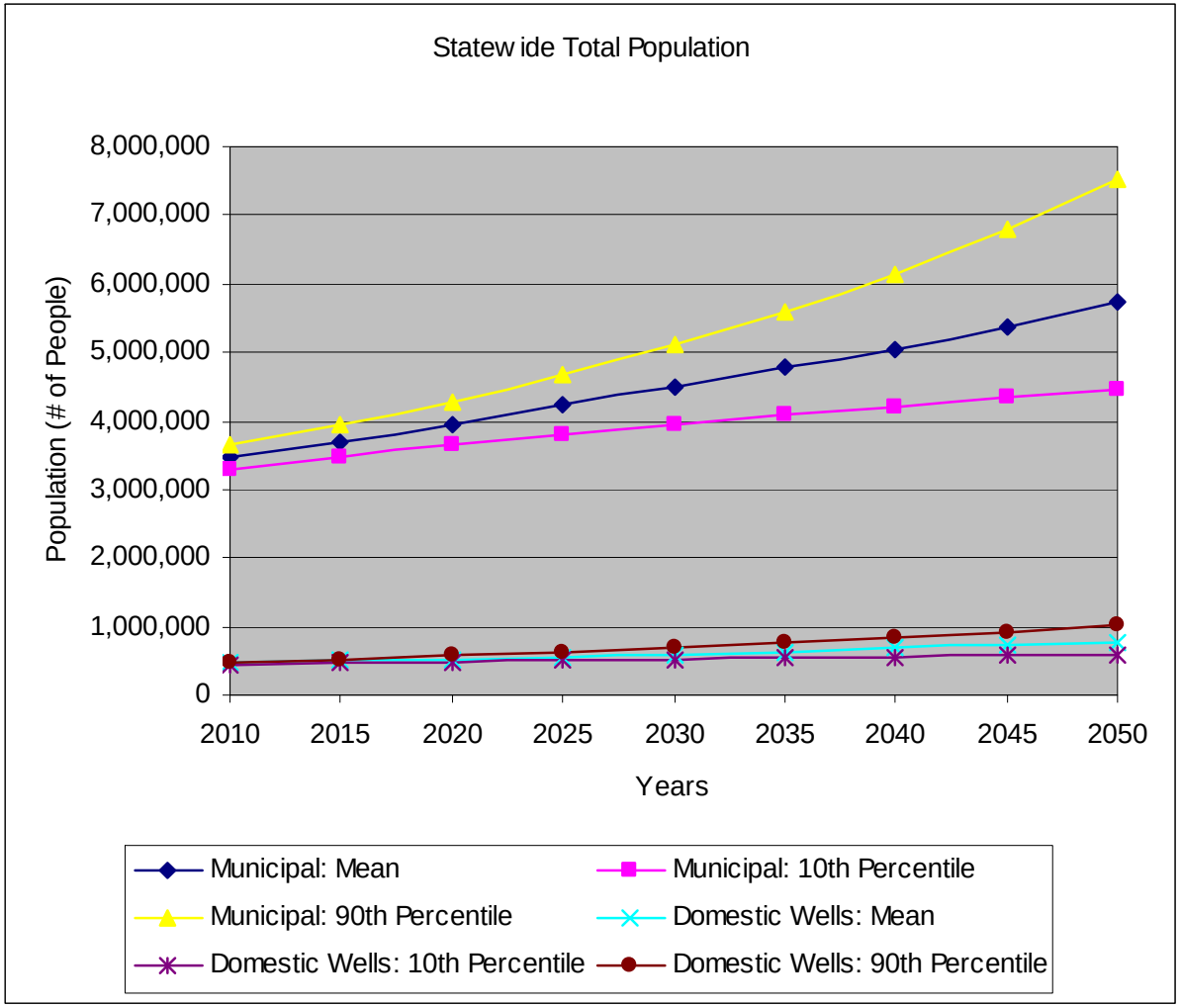


Figure F-2. Example – 2050 Per Capita Water Demand by Month for Deschutes County

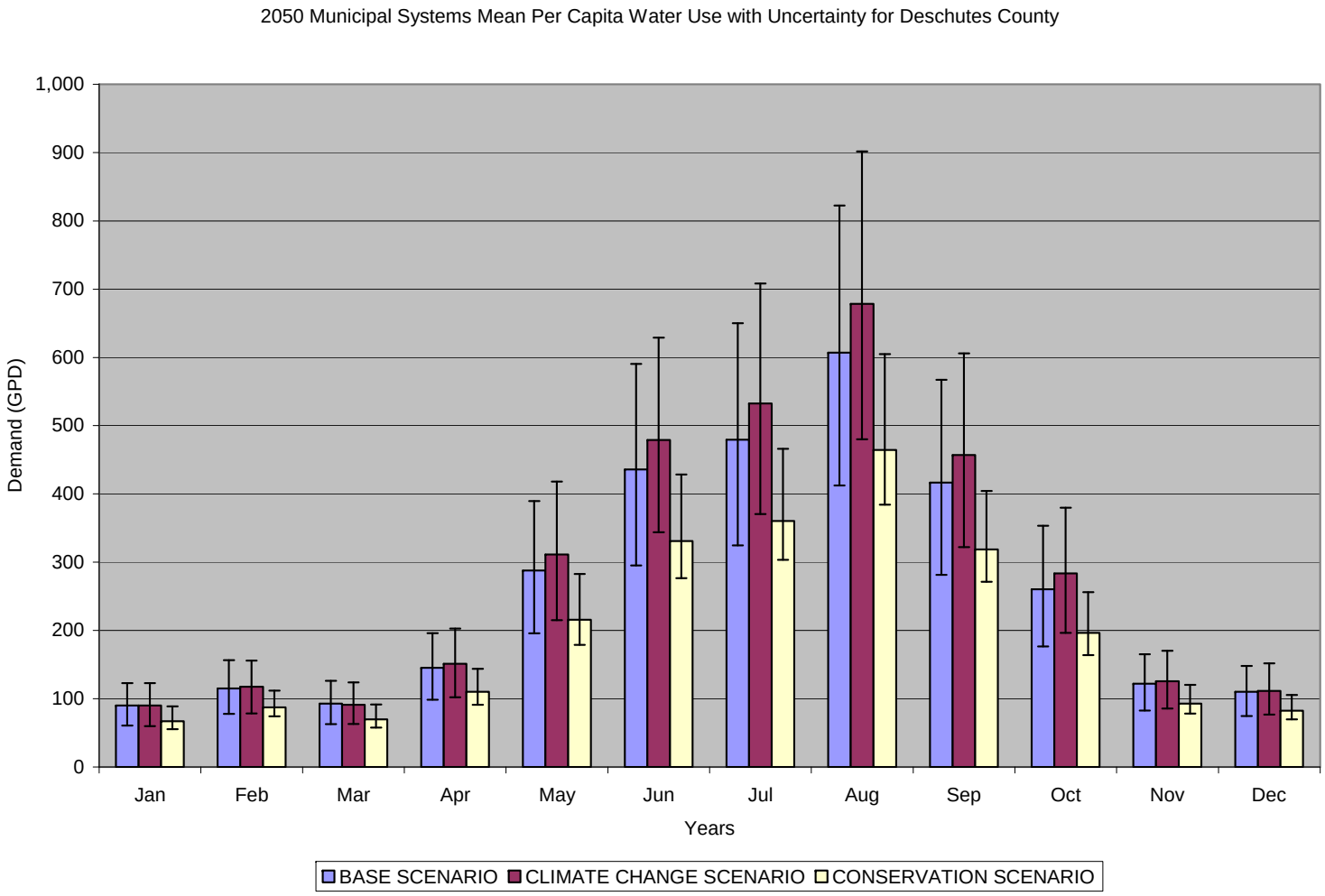


Figure F-3. Example – Crop Acreage Uncertainty Range for Deschutes County

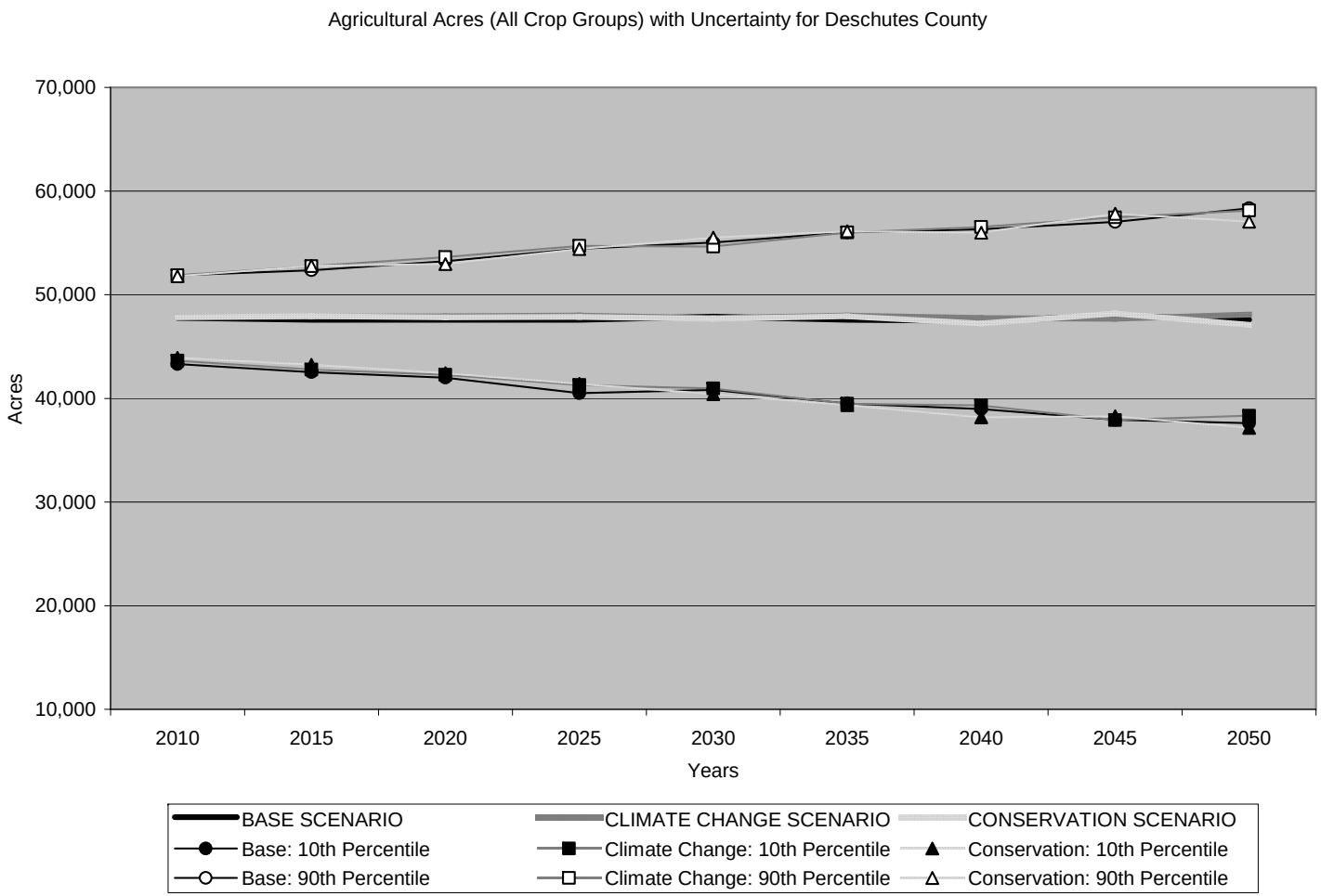


Figure F-4. Example – Crop Irrigation Requirement Range for Alfalfa/Hay for Baker County

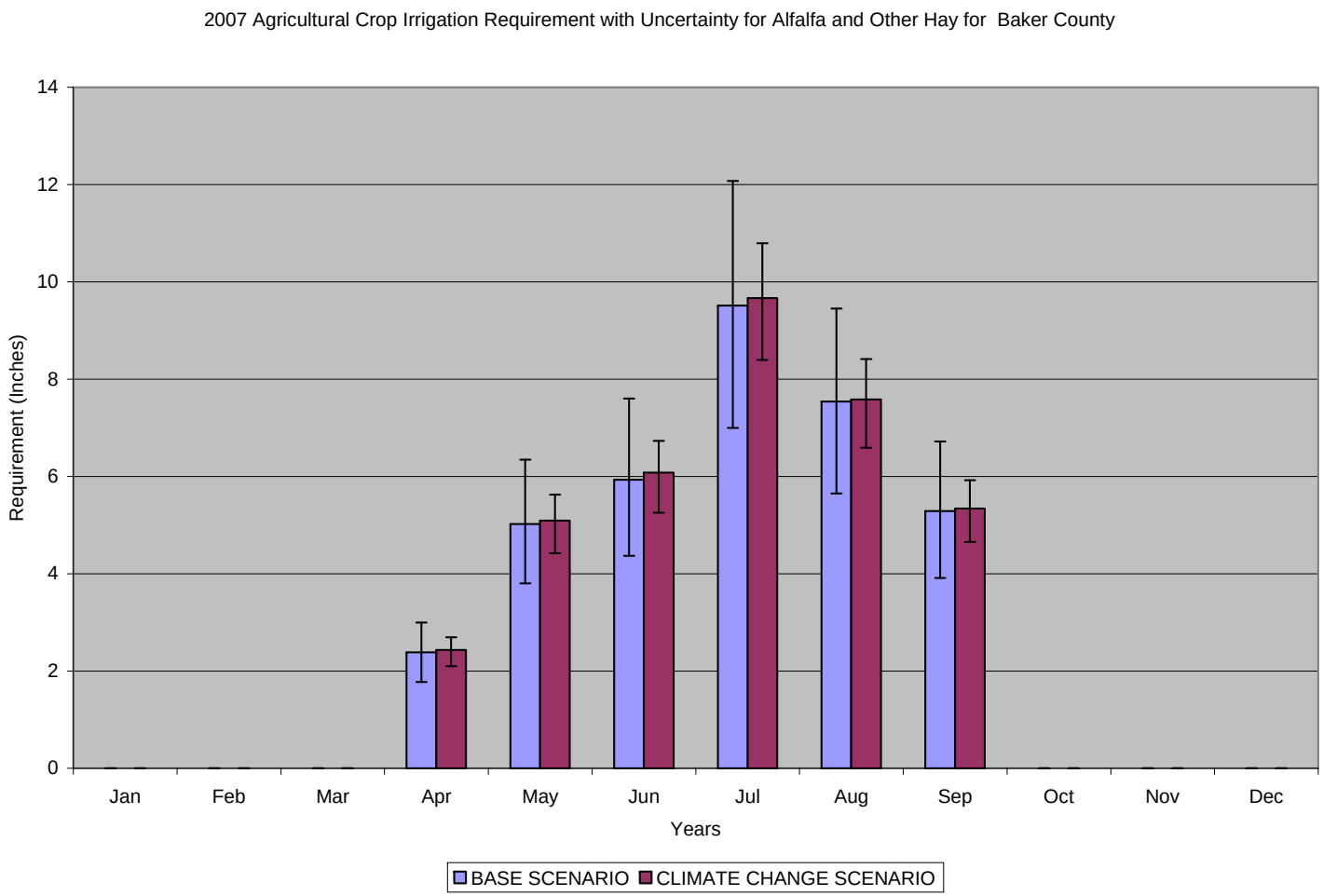


Figure F-5. Example - Irrigation Efficiency Range for Alfalfa/Hay for Deschutes County

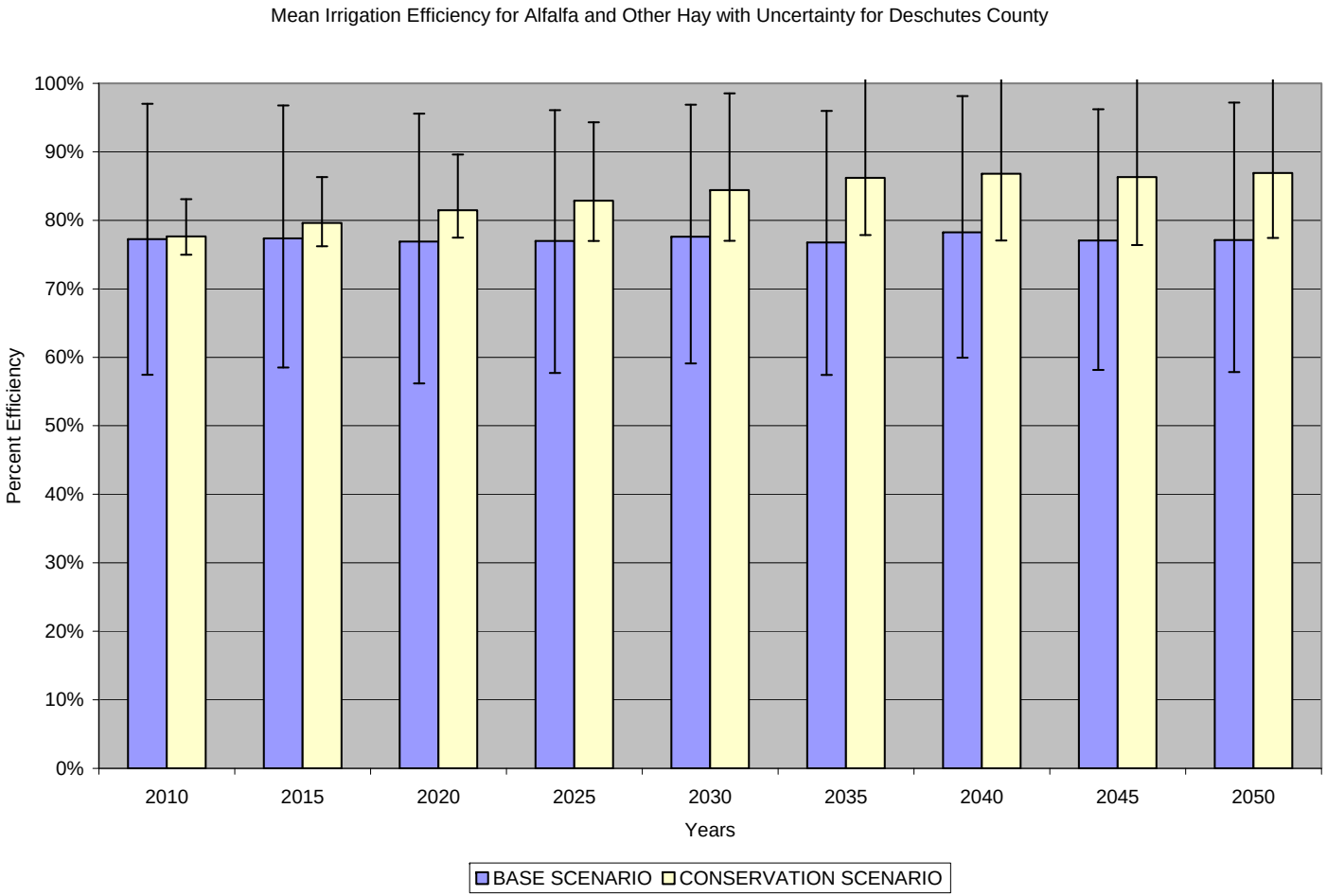
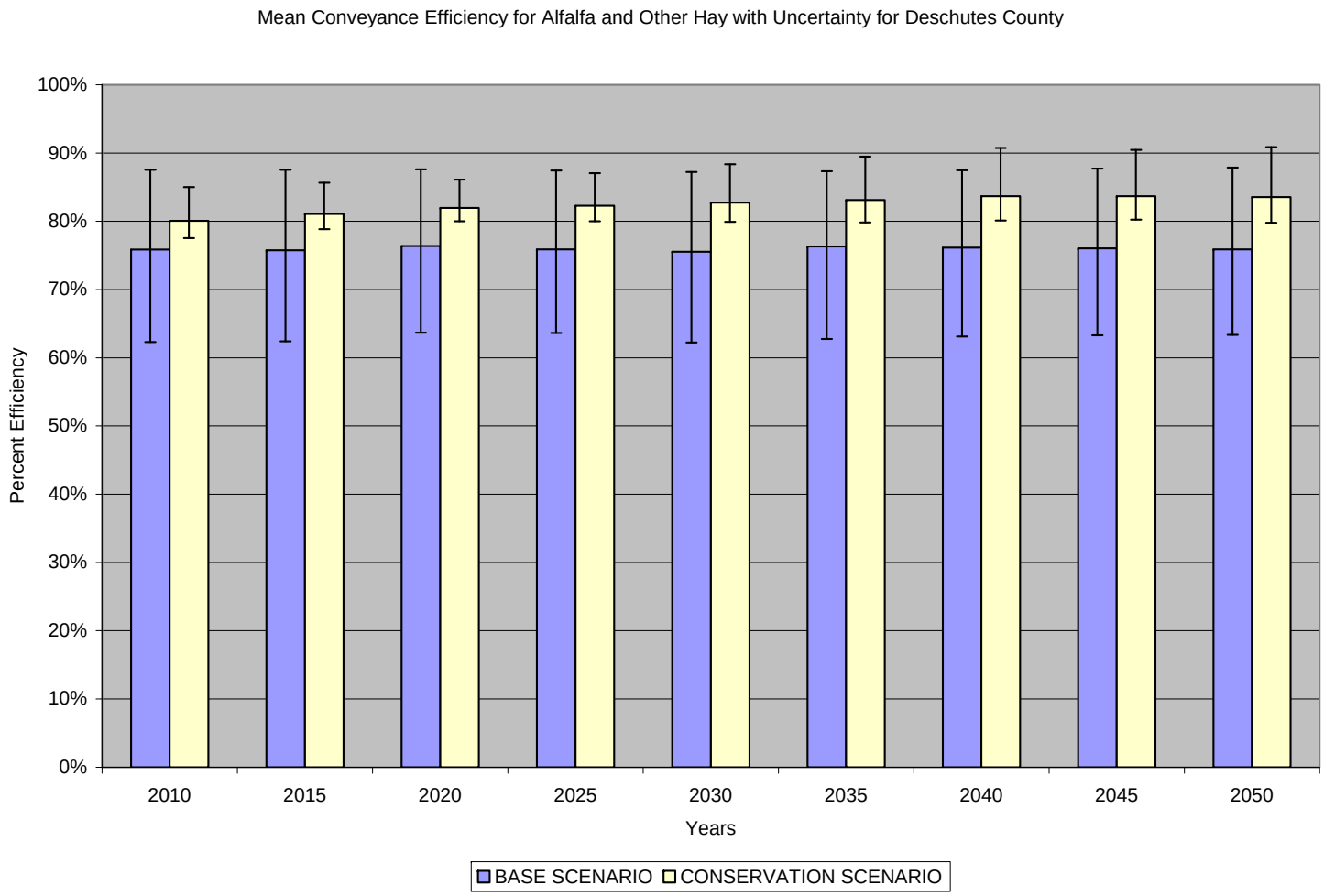



Figure F-6. Example – Conveyance Efficiency Range for Alfalfa/Hay for Deschutes County