Future Ground Water Demand in the Deschutes Basin

DWA Final Report

August 2006

David Newton, P.E.[1]

Mathias Perle[1]

Jake Polvi, E.I.T.[1]

[1], Newton Consultants, Inc. 521 SW 6th Street, Suite 100, Redmond, OR, 97756; (541) 504-9960
dnewton@newtonconsultants.com

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Deschutes Water Alliance
Future Groundwater Demand in the Deschutes Basin – August 2006

Prepared by:

David Newton Newton Consultants, Inc.
Mathias Perle Newton Consultants, Inc.
Jake Polvi Newton Consultants, Inc.

Feedback and comments were received by:

Patrick Griffiths City of Bend
Tom Hickman City of Bend
Pat Dorning City of Redmond
Ray Johnson City of Redmond
Kyle Gorman Oregon Water Resources Department
Tod Heisler Deschutes River Conservancy
Bruce Aylward Deschutes River Conservancy
Kate Fitzpatrick Deschutes River Conservancy
Brett Golden Deschutes River Conservancy
Steve Johnson Central Oregon Irrigation District & Deschutes Basin Board of Control
Jan Lee Swalley Irrigation District
Kathy Kihara Bureau of Reclamation
Bonnie Lamb Oregon Department of Environmental Quality
Jan Houck Oregon Parks & Recreation Department
Steven Marx Oregon Department of Fish and Wildlife

FOREWORD

BACKGROUND

The upper Deschutes Basin comprises about 4,500 square miles of watershed between the highland areas to the east, south and west, and Lake Billy Chinook to the north. The Central Oregon area, located within the upper basin, is experiencing rapid growth and changes in both lifestyle and land uses. Along with these changes, long-recognized water resources issues have become more important and a number of others have developed.

More effective use of water resources to broaden the benefits of water use in connection with irrigation, stream flow restoration, protection of scenic waterway flows and water quality improvements has long been an important resource management issue in the upper basin. Other developing issues include need for safe, reliable water supply for future basin needs, urbanization of irrigated lands and impacts on agriculture, and needs to protect flows for fishery, recreation and other instream uses.

The significance of basin water issues has increased considerably over the last few years. The rapid growth and subsequent water needs that the region is experiencing presents an opportunity to study these issues in more detail given changing values and availability of funding. Consequently, water usage and availability are now a major topic in discussions among basin water suppliers and planners. Due to increased dialogue and awareness relative to water issues, regional urban water suppliers, irrigation districts and other private, government and individual water users now recognize their interdependency in the use, management and protection of Deschutes Basin water resources. This recognition and related dialogue enjoined the major water suppliers in a common vision that commits energy and resources in a collaborative effort to respond to basin water issues.

Water supply, water quality, flow depletion and irrigation district urbanization issues in the upper Deschutes Basin establish the framework for need for the Deschutes Water Alliance. Mutually beneficial opportunities exist for municipalities and flow restoration interests to obtain needed water supply and for irrigation districts to resolve urbanization and conservation issues. Some of the key management considerations involved with these opportunities:

- Full appropriation of surface waters
- Declaration of groundwater restrictions and related mitigation requirements
- Dependency of municipal water providers on groundwater for future needs
- Diversion of substantial river flows by irrigation districts
- 303(d) listings for water quality parameters and need for TMDLs throughout the Deschutes and Crooked Subbasins.
- Protection of scenic waterway flows in the lower reaches of the Deschutes and Crooked Rivers

- Potential Endangered Species Act issues
- Re-Introduction of anadramous fish species in the Deschutes and Crooked Rivers
- Rapid growth, urbanization and land-use change in the basin

Organization

The Deschutes Water Alliance (DWA) was formed by four major basin partners to develop and implement integrated water resources management programs in the upper Deschutes Basin. The partners include**:**

- Deschutes Basin Board of Control (DBBC): represents seven irrigation districts in the basin including BOR's Deschutes Project (North Unit Irrigation District) and Ochoco Projects formed under ORS 190.125.
- Central Oregon Cities' Organization (COCO): which is comprised of cities in the basin and affiliated drinking water districts and private companies providing potable water supply.
- Deschutes River Conservancy (DRC):
- Confederated Tribes of Warm Springs (CTWS)

Goals and objectives

The DWA is investing in managing the water resources of the Deschutes Basin in a unified way to provide:

- Reliable and safe water supply for the region's future municipal and agriculture needs and sustained economic viability considering growth, urbanization and related effects on water resources;
- Financial stability for the Basin's irrigation districts and their patrons;
- Protection of the fishery, wildlife, existing water rights, recreational and aesthetic values of the Deschutes River along with stream flow and water quality improvements;
- Focus on maintaining the resource and land base in the Basin, consistent with acknowledged comprehensive land use plans; and
- An institutional framework that supports the orderly development of local water markets to protect participants and create an "even playing field" for water transactions.

These considerations are key elements to be incorporated into development of the integrated water resources management and restoration program.

Approach

Mutually beneficial opportunities exist to boost water supply for agriculture, municipal needs and stream flow for fish, wildlife and water quality improvements. Mutually beneficial

opportunities also exist through integrated planning for irrigation districts to resolve urbanization issues. In order to develop a framework and program to achieve these objectives, the DWA is implementing five planning studies under a Water 2025 Program grant to generate facts and background information necessary for program formulation. The planning study results will be synthesized into a Water Supply, Demand and Water Reallocation document with project scenarios, five-year implementation bench marks and 20-year timeframe. The five planning studies are as follows:

- Irrigation District Water Conservation Cost Analysis and Prioritization-an evaluation and prioritization of opportunities to save water through piping and lining of canals, laterals and ditches, as well as through on-farm conservation technologies.
- Growth, Urbanization and Land Use Change: Impacts on Agriculture and Irrigation Districts in Central Oregon. (Title in Water 2025 Grant was *Impacts of Urbanization on Irrigable Lands*) -an inventory of amounts, patterns and rates of district water rights becoming surplus due to urbanization or other changes in land use patterns in Central Oregon and corresponding impact on district assessments.
- Reservoir Management (Title in Water 2025 Grant was *Reservoir Optimization Study and Water Quality*)- prepare rapid assessment of potential gains from optimization of existing reservoirs and their potential impact on improving flow and quality, and prepare terms of reference for more formal and rigorous assessment.
- Future Groundwater Demand in the Deschutes Basin (Title in Water 2025 Grant was *Municipal Water Demand*)-assessment of the water supply needs, quantity and timeline of the Basin's regional urban suppliers.
- Instream Flow in the Deschutes Basin: Monitoring, Status and Restoration Needs (Title in Water 2025 Grant was *Measurement, Monitoring and Evaluations* Systems)- In-stream Flow Needs for Fish, Wildlife and recreation along with Measurement, Monitoring and Evaluation Systems-assessment of the suitability and completeness of existing flow measurement sites and existing Water Quality and Monitoring Plan for the Upper Deschutes Basin and prepare funding and implementation action plan.

EXECUTIVE SUMMARY

Background

The Deschutes Water Alliance (DWA) is investing in several water resources management provisions for the upper Deschutes Basin. One of the key provisions is to provide reliable and safe water supply for the region's future agriculture and municipal needs taking into account sustained economic viability considering growth, urbanization and related effects on water resources.

The initial scope of this planning study involved estimating quantity and timing of future needs and sources of water for the regional urban water suppliers. The regional urban suppliers include: Avion Water Company, Cities of Bend, Prineville, Redmond and Sisters, and the Deschutes Valley Water District, supplying Culver, Madras and Metolius. After further study, however, it became apparent to DWA members that this scope should be further refined and expanded to include estimated ground water demand for other water users to the year 2025

The report title was therefore changed from *"Municipal Water Demand"* to *"Future Ground Water Demand in the Upper Deschutes Basin"*. Estimates for future ground water demand were made for the following water use categories:

- Demand within Urban Growth Boundaries (UGBs),
- Demand for uses outside UGBs,
    - Demand based on pending groundwater permits on file with OWRD,
    - Demand based on other potential future uses in the basin including destination resort development, and
    - Demand based on exempt uses (domestic use less than 15,000 gallons per day and irrigation of less than one-half acre, and commercial uses less than 5,000 gallons per day do not require water use permit and are classified as exempt uses).

This evaluation was completed in conjunction with four other planning studies to develop a basis for planning and implementing water resources management provisions to help achieve the goals and objectives of the DWA.

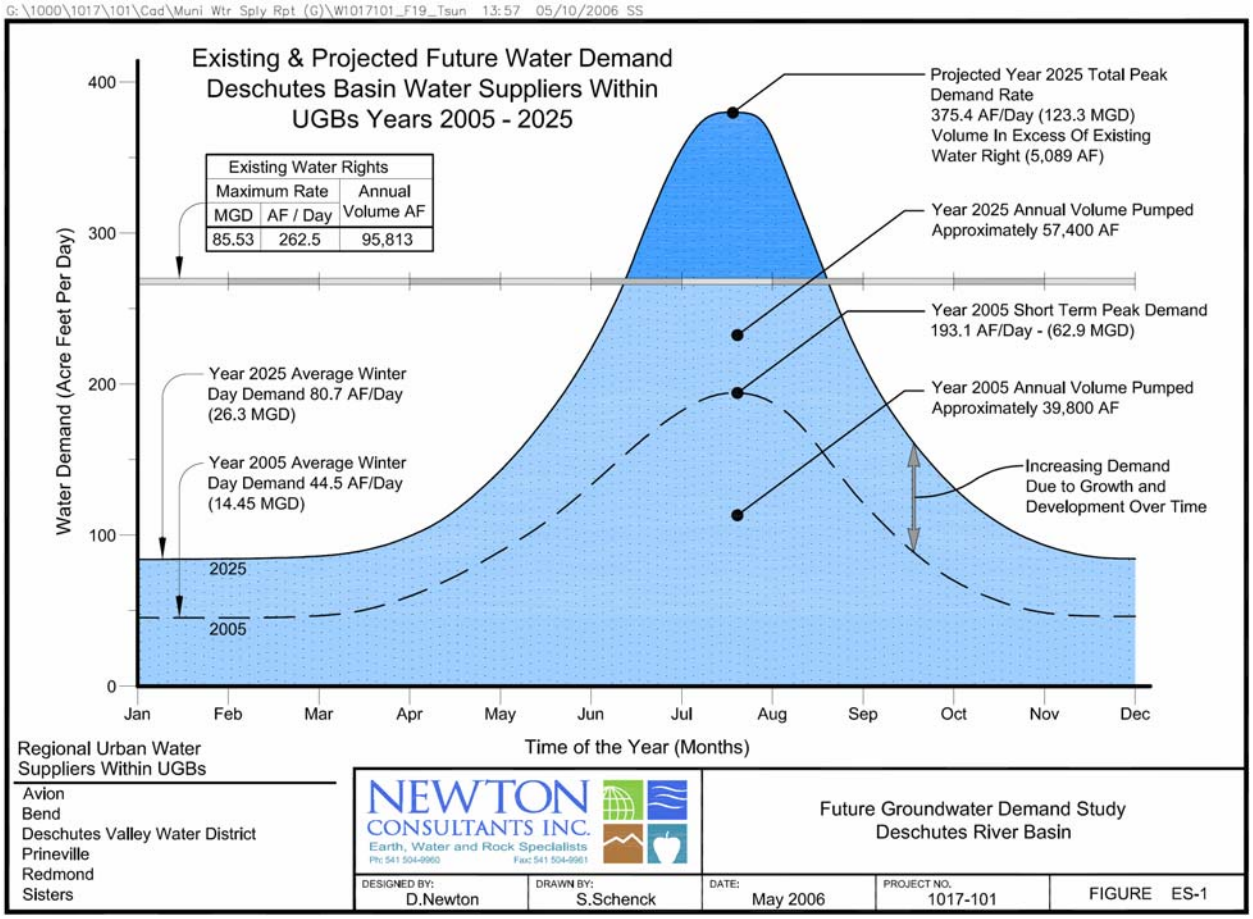
Findings

Demand for Future Uses Inside Urban Growth Boundaries - Regional Urban Water Suppliers

The regional urban water suppliers serving users within the UGBs presently hold water right permits and certificates issued by the Oregon Water Resources Department (OWRD). These water rights allow the suppliers to use public waters for municipal and quasi-municipal purposes.

Water use by the water suppliers within the UGBs varies over the year, similar to most other water uses. The maximum rate of water use is highest during the hotter periods of summer, usually during July and August. Irrigation during this time is the major component of increased water use. The rate of water use decreases in fall, winter, spring, and cooler times of summer, largely due to decreasing temperature and irrigation needs. An illustration of water use by water suppliers within the UGBs over the year is shown below in Figure ES-1 (dashed curve for the year 2005).

Figure ES-1 Present and Projected Water Use By Suppliers Within UGBs



The amount and timing of future water needs depends on rates and patterns of population growth in the upper basin, and how this growth is managed. Future water needs within the UGBs were estimated with population projections reported by the Coordinated Deschutes County Forecast, Portland State University and in water master plans prepared by the regional suppliers. Population trends for the next 20 years are uncertain. Variations in trends will impact amount and timing of estimated water needs; however, the estimates reflect the potential magnitude of future needs as a planning benchmark for developing water supply plans in conjunction with DWA objectives.

Although population growth is driving the increase in water demand, existing water rights held by water suppliers within the UGBs are sufficient to supply average day water demand during fall, winter, spring and most of the summer for approximately the next 20 years (through to 2025). However, given potential projected population growth rates, increases in peak summer demand rates during the next 20 years will exceed maximum water use rates authorized by existing water rights during short, hot weather periods of summer (usually during July and August). If the projected population growth rates occurred, new water rights would be required for these short-term peak needs. The potential future water right needs for the water suppliers within the UGBs is shown as the dark blue shaded area at the top of the curve in Figure ES-1.

Given assumptions relative to population growth and peak demand period, it was estimated that water rights would be needed for an approximate volume of 5,089 acre-feet to satisfy annual

peak short term summer demand. This translates to approximately 56.92 cubic feet per second (CFS), or 36.87 million gallons per day (MGD) based on the assumption that peak demand flow rates are sustained over a continuous 45-day period. Estimated future water needs to the year 2025 for each of the regional urban water suppliers inside the UGBs are presented in the Table ES-1 below. New water rights for the future peak needs could be obtained incrementally in relatively small amounts over time.

Table ES-1 Estimated Future Needs for Water Suppliers Within UGBs.

SUPPLIER WITHIN UGBs	Additional Flow Rate Need (MGD)	Additional Flow Rate Need (CFS)	Estimated Annual Volume Needed (acre-feet)
Bend	10.27	15.89	1,416
Avion	10.63	16.44	1,465
Redmond	12.35	19.11	1,703
Sisters	0.12	0.19	17
DVWD	0	0	0
Prineville	3.5	5.48	488
TOTALS	**36.87**	**56.92**	**5,089**

The dark blue area (peak volume) in Figure ES-1 represents the total volume of additional water to satisfy annual peak short term summer demand based on population projections. This volume is shown as the total estimated annual volume needed in Table ES-1. The regional urban water suppliers within UGBs have applied for groundwater permits however. Mitigation obligation according to OWRD would therefore be based on these pending permits. The additional volume needed given pending permits for the regional urban water suppliers within UGBs would therefore be 5,536 acre-feet (compared to 5,089 based on population forecasts). These estimates are based on peak water use according to pending permit applications in excess of existing water rights.

Although the scope of this paper is focused on future water needs of the water suppliers within the UGBs, the needs of other potential users were also evaluated on a preliminary basis to help reflect total potential new water demand in the upper basin over the next 20 years.

Pending Ground Water Permit Applications for Other Uses Outside UGBs

Ground water permit applications are presently on file with the OWRD for a range of uses. These applications represent an estimated annual water use of approximately 18,066 acre-feet. Based on consumptive factors used by the OWRD for the different uses, the volume of consumed water would be approximately 7,623 acre-feet (consumed water is the volume of used water that does not return directly to the local hydrologic system). These groundwater permit applications are pending and create a real potential for water demand. However, cursory investigation indicates that many of these permits may not be pursued at the requested rate and suggest artificially created demand. It is possible that the actual permit application rates could be substantially reduced. Estimated demands for the various types of proposed water use are presented in the Table ES-2 below.

Table ES-2 Pending Ground Water Permit Applications for Other Uses Outside UGBs

REQUESTED USE	Requested Rate / Vol (CFS)	Acres of Irrigation (ac)	EstimatedAnnual Volume (acre-feet)	Volume of Consumptive Use (acre-feet)
Irrigation	13.4695	1,099.50	3,299	1,979
Industrial	1.1220	NA	811	81
Group Domestic	0.2490	NA	90	18
Pond Maintenance	22.1800	NA	22	7
Quasi-Municipal	38.3110	NA	13,844	5,538
TOTALS	**75.3315**	**1,099.50**	**18,066**	**7,623**

Other Potential Future Ground Water Demand Requiring Permits

Current pending applications do not represent the full extent of demand over the next 20 years. Additional supply for potential future needs was also considered. Several destination resorts are in the development and planning stages in the upper basin. Water needs for a number of these is accounted for under pending quasi-municipal groundwater applications; however, development of other future resorts is possible. Needs for new ground water supply for future potential resorts depends on whether resorts are sited on irrigated or dry lands, and whether they are sited near existing irrigation delivery systems. It is possible that some resorts will utilize existing surface water rights to meet irrigation demand, while using groundwater to meet domestic and lawn demand, thereby reducing the need for new ground water supply. It is also possible that other future resorts will have no access to existing water rights and will depend totally on new ground water supply. Water use by these potential future developments will also vary with seasons over the year and will be similar to most other water uses illustrated above. The general pattern of annual water use under a new permit is illustrated in Figure ES-2 below.

If new water rights must be obtained for water supply, the annual volume of demand for new users could be large relative to future needs in excess of the water rights presently held by the regional suppliers within UGBs. This new potential demand volume is represented by the blue area in Figure ES-2 below. Many residential development projects in rural areas, including destination resorts, outside UGB service areas are in this category of new water users.

Total annual ground water demand to 2025 for these potential future uses is estimated at 7,890 acre-feet. These results are presented in Table ES-3 below.

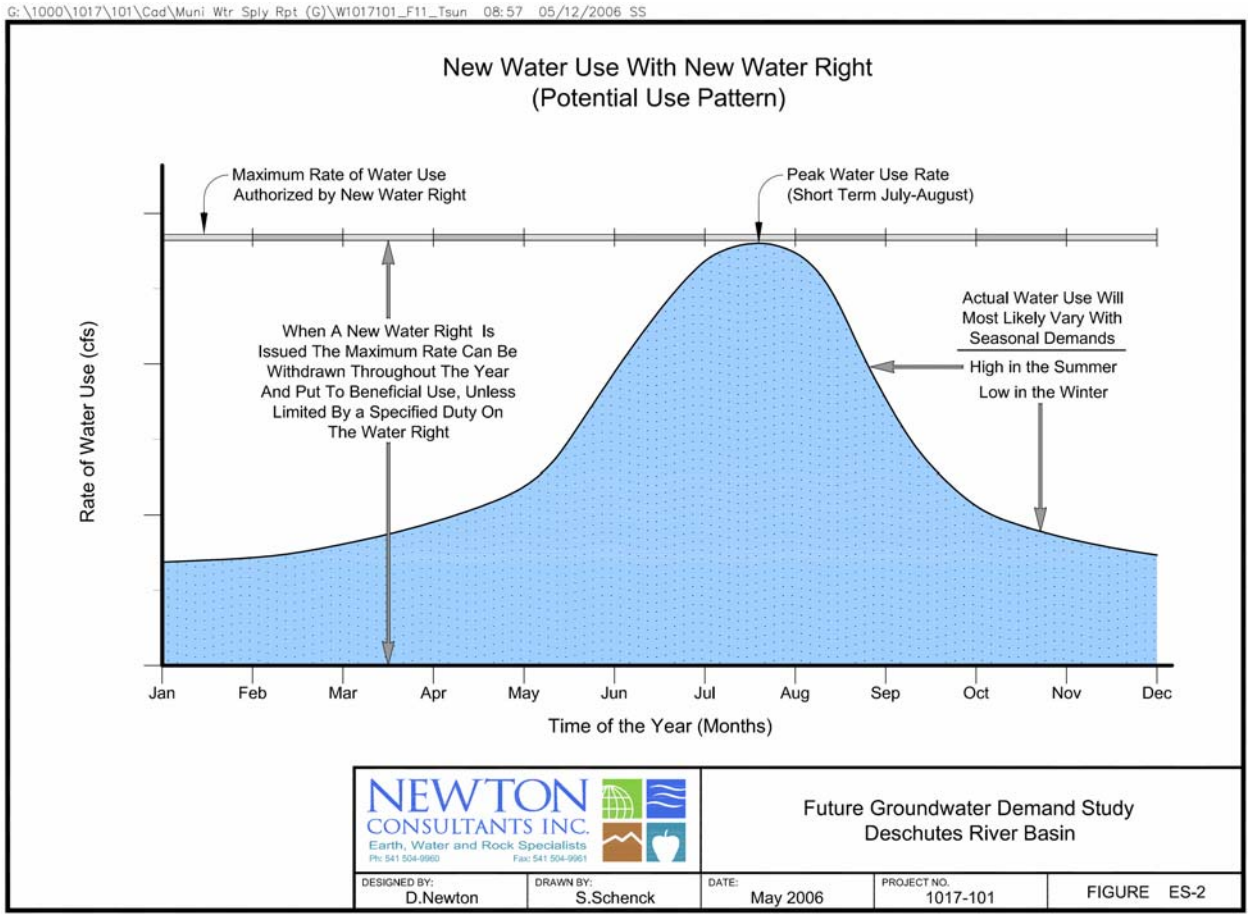
Table ES-3 Ground Water Demand for Potential Future Uses

Water Use Description	Estimated Annual Volume (acre feet)	Volume of Consumptive Use (acre-feet)
5 Destination Resorts	6,630	3,315
Additional Irrigation of 120 ac (120 ac @ 3 af / ac)	360	360
Additional group domestic & other (2.5 cfs peak with 1.25 cfs annual avg)	900	450
TOTAL	**7,890**	**4,125**

This is a speculative estimate based on 5 potential future resorts needing to satisfy their entire water supply need from new groundwater rights, 120 acres of new irrigation and additional

group domestic uses. Given consumptive factors for the different uses, the volume of consumed water would be approximately 4,125 acre-feet. .

Figure ES-2 Projected Water Use For Other Potential Future Ground Water Demand Requiring Permits



Exempt Ground Water Uses

Ground water is also used for domestic needs in rural areas without municipal or other water utility service. Most of the rural domestic demand is classified as an exempt use by the OWRD. Exempt use means water right permits are not required if domestic use is less than 15,000 gallons per day and irrigation is less than one-half acre, or commercial use is less than 5,000 gallons per day. OWRD records indicate approximately 20,000 exempt wells currently exist in Deschutes, Jefferson and Crook Counties. By 2025, it is estimated that the number of exempt wells could grow to 32,000. The estimated total annual water uses for the current and projected (2025) number of exempt wells are described in Table ES-4. These numbers are based on OWRD estimates of daily usage rates per well of 1,000 gallons per day (GPD), a 40% consumptive factor and 600 new exempt wells per year.

Table ES-4 Exempt Ground Water Use

	Number of Exempt Wells	Estimated Annual Volume (acre-feet)	Volume of Consumptive Use (acre-feet)
Current Estimate	20,000	22,400	8,960
2025 Estimate	32,000	35,844	14,338
Estimated Future Increase	**12,000**	**13,444**	**5,378**

Summary and Issues

The total volumes of water subject to mitigation and numbers of irrigation water rights that would be needed to meet these mitigation obligations for the projected future demands are summarized in the Table ES-5 below. The total estimated annual water demand out to 2025 for all projected uses in the basin subject to this study is estimated at 48,934 ac-ft. Given consumptive factors for the different uses, the volume of consumed water would be approximately 22,699 acre-feet. The percent of total consumption by each category of water use in the basin is also listed in Table ES-5.

Table ES-5 Estimated Total Volumes of Water Use and Mitigation Obligations

Water Use	Estimated Annual Volume (acre-feet)	Volume of Consumptive Use (acre-feet)	Percent of Total Consumptive Use %	Volume of Consumptive Use Subject to Mitigation (acre-feet)	Mitigation Obligation (acres)
Water Suppliers Inside UGBs[1]	17,600	8,800	38.8	2,768	1,538
Pending Groundwater Permits-Other Uses Outside UGB	18,066	7,623	33.6	7,623	4,235
(Destination Resorts, Domestic…) Outside UGBs	7,890	4,125	18.2	4,125	2,292
Projected Exempt Groundwater Uses (exempt wells)[2]	5,378	2,151	9.5	NA	0
TOTALS	**48,934**	**22,699**	**100**	**14,516**	**8,065**

[1] See Figure ES-1 for details on total consumptive use and volume subject to mitigation

[2] Exempt well consumptive uses are representative of projected new wells in the basin to 2025

Under Oregon Statute (HB 3494) new ground water permits are issued only when potential pumping effects on stream flow or other senior water rights are offset by a mitigation process in accordance with Oregon Administrative Rules (OAR 690.505). Therefore any new groundwater permits issued would also need water for mitigation. The water suppliers within the UGBs (given projected population growth rates), pending groundwater permit holders for other water uses and other potential future uses would all need water for future needs and for mitigation. Mitigation is required for the amount of used water that is consumed.

Practical opportunities exist for the water suppliers both inside and outside UGBs to obtain mitigation water through irrigation district transactions involving conversion of lands from farm to urban uses. For each acre of irrigation water right transferred instream for mitigation, 1.8 acre-feet of mitigation credit can be obtained. Table ES-5 shows that approximately 8,065 acres would satisfy the mitigation obligation for all estimated future demand described earlier. Irrigation district lands with water rights inside the Bend and Redmond UGBs and Urban Reserve Areas (URA) are the most susceptible to development and land use changes which can

provide water for mitigation purposes. A more detailed analysis on how these mitigation obligations could be met can be found in the companion DWA report "*Growth, Urbanization and Land Use Change: Impacts on Agriculture and Irrigation Districts in Central Oregon*".

Exempt wells do not currently have to mitigate for their ground water withdrawals. An important issue to consider is that if projected exempt well development proceeds at the pace outlined above, this use of groundwater will total 9.5% of total new groundwater demand over the next 20 years. Yet, as noted in Table ES-5, this demand is not mitigated – landowners are not required to acquire groundwater mitigation. Future policy discussion regarding the groundwater mitigation program may need to consider how to address this issue.

Current consumptive use of groundwater is estimated at 35,895 AF in the companion DWA report "*Instream Flows in the Deschutes Basin*". Additional needs by the end of the 20-year period to 2025 suggest roughly another 22,699 acre-feet/yr of consumptive use (Table ES-5). Total consumptive use of groundwater would then be 58,594 acre-feet/year of a total recharge of 3.3 million acre-feet. Use would be 1.8% of annual groundwater flux. Although ground water is physically available to meet future needs, future ground water pumping could measurably reduce stream flows due to hydrologic connectivity between the aquifer and surface waters in the upper basin. Groundwater mitigation provided through leases, transfers and other approved projects would have the intent of reducing consumptive use at the appropriate point of return flow, particularly in the confluence area around Lake Billy Chinook. In other words the increase in consumptive use of groundwater would be offset by a reduction in consumptive use of surface water. As part of the analysis of an overall basin water management plan these activities and their impacts will be examined further as the requisite surface and groundwater modeling tools are developed and refined.

While surface waters are fully appropriated under existing water rights (mostly irrigation), the water suppliers within the UGBs will most likely depend on ground water and municipal water conservation to meet additional demand. Conservation measures already implemented by water suppliers within UGBs have helped reduce demand, thereby putting off the date at which future supply is required. The proportion of future supply that could be met with conservation measures is related to demand management and investment in new conservation technology and education by basin water suppliers. Conservation alone is not adequate to fully meet future estimated demand for the regional urban suppliers for uses within the UGBs, although more analysis is needed and is underway by the suppliers. In general, it is estimated that conservation can reduce demand on new supply by about 10 to 20 percent on average. Future demand will therefore most likely be met by a combination of municipal water conservation measures and new ground water permits.

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TABLES

DEFINITIONS

Definitions of water-use words included in this paper are provided below.

Oregon Water Code: Under Oregon law, all water is publicly owned. Public waters from streams, lakes or under ground sources can be used. Cities, farmers, factories and other water users must obtain a permit or water right to use public waters. Four fundamental code provisions follow:

- Surface or ground water may be legally diverted for use for only beneficial purposes without waste.
- The priority date of a water right determines who can use the water during times of shortage. The more senior the water right, the longer water is available for use under the right during times of shortage.
- A water right is attached to the land where the right was established, as long as the water is used. If the land is sold, the water right goes with the land to the new owner.
- A water right must be used at least once every five years as provided in the water right. With some exceptions, the right is considered forfeited and subject to cancellation after five consecutive years of non-use.

Water Right Permit: Permit issued to the water user by the Oregon Water Resources Department (OWRD) allowing the user to begin constructing the water system and begin use of the water.

Perfected Water Right: If the water user has met all conditions of the permit, a water right certificate is issued authorizing use of water up to the amount beneficially used under the permit, after the water system is constructed. The amount of water allowed in the water right will be both an instantaneous rate, and if for irrigation, an annual volume. Historically, municipal water rights specify only a maximum allowed instantaneous rate of use.

Ground Water Right: A water right for beneficial use of water obtained from a ground water source.

Rates of Water Demand: The rate or volume of water required to satisfy needs for a given use at a given time. Rates of demand vary, primarily according to seasonal variations, as indicated below:

- *Peak Demand**:*** The maximum rate or volume of water required to satisfy needs for a given use. Peak demand can range from 135 percent of average annual demand seasonally, 155 to 180 percent of average annual demand on a day basis, to 255 to 350 percent on an hour basis. Peak demand generally occurs during several days during hotter periods of summer (usually July and August) in response to irrigation needs.

- *Average Day Demand**:*** The average rate or volume of water required to satisfy needs during a normal day outside the peak demand period.

- *Average Winter Day Demand:* The average rate or volume of water required to satisfy needs for a given use during a typical winter day, generally, the lowest rate of water use.

Per Capita Water Demand: The rate of water use in gallons per day per person. Generally used in municipal or urban water supply planning. In this paper, it is expressed as gallons per capita per day (gpcd).

Mitigation: Provisions to offset impacts of ground water pumping on surface waters, stream flow and other senior water rights.

Exempt Water Use: Ground water use that does not require a water right permit, or perfected water right. A ground water use is exempt if the use is less than 15,000 gallons per day for domestic purposes, or if less than one-half acre of land is irrigated by ground water use.

Rates of Water Flow: Rate at which water is used. The rate is usually expressed as cubic feet per second (cfs) on water rights permits and perfected water rights certificates. One (1) cubic foot per second (cfs) is a flow rate that will deliver one cubic foot of water in one second. One cfs is equivalent to flow rates of:

- 7.48 gallons per second
- 448.8 gallons per minute
- 646,272 gallons per day
- 1.98 acre-feet per day

Measurement of Water Volume: The volume of water use is the total amount used over a period of time. Volume is the product of the rate of water use times the time over which the water is used at the specified rate. One (1) acre-foot is the volume of water which will cover one acre to a depth of one foot and is equal to:

- 43,560 cubic feet
- 325,851 gallons

Aquifer: An underground geologic formation or strata containing water in its interstices, with sufficient permeability to yield ground water to a well in amounts suitable for a beneficial use.

Aquifer Recharge: Water gained by an aquifer from infiltration of water from rain, melting snow, streams, lakes and from artificial sources including canal leakage and irrigation.

ASSUMPTIONS

Estimation of future water supply needs are subject to a number of variables that can involve rather detailed analysis to account for their impact. The water suppliers provide water for several types of uses, including municipal, industrial, commercial, irrigation and domestic purposes. Prediction of how these various needs will change in the future depends on future comprehensive land use planning and zoning decisions. Uncertainty in this regard translates to uncertainty in predicting future water needs for these different types of uses.

Future water needs also depends on population growth. Timing for bringing additional water supply on line depends on the rate at which populations served by the water suppliers within the UGBs increase over time. The rate of population growth can vary widely, depending on the economic, demographic, land use and capacity of resources and services to support growth at a given rate.

In summary, there are some variables which relate directly to future water supply needs that cannot be quantified with certainty. Assumptions must be used in such cases for examining potential future water needs of the water suppliers within UGBs. The following assumptions were used to develop estimates of future water needs for the water suppliers within UGBs.

- The average population growth rate for the next 20 years is 2.2 percent based on the Deschutes County Coordinated Forecast. In many cases, water suppliers developed population forecasts independent of the County forecast and rely on these forecasts for planning purposes. In these cases, forecasts were discussed and confirmed for applicability with supplier representatives, and then used to estimate their water needs over the next 20 years. Population growth rates used for each supplier are summarized below.

SUPPLIER	**GROWTH RATE**
Avion Water Company	2%
Bend	2.2% (County Rate)
Culver	2%
Madras	4% to 2015 3% 2015 to 2020 2% 2020+
Metolius	2%
Prineville	3%
Redmond	3.97%
Sisters	3.13%

- Industrial, commercial, school, residential and landscape water use is included in overall per capita water use rates obtained from the suppliers. Therefore per capita water use rates provided by the suppliers are assumed to provide an adequate basis for estimating future water needs.

- Total water demand for each supplier is expressed in terms of per capita use, which ties water demand to population. Therefore, it is assumed that future water needs of the suppliers can be estimated with population forecasts and per capita water demand.
- Per capita water demand for each supplier is expressed in terms of per capita use for average peak day water demand, average day water demand and average winter day water demand. Therefore, it is assumed that future water needs of the suppliers can be estimated for average peak day, average day and average winter day demand utilizing population projections.
- The peak day water demand season for the suppliers is in the hotter periods of summer, usually during July and August. Although the total number of days in which peak demand rates are in effect generally ranges between 14 to 25 days that are not necessarily consecutive, a period of 45 consecutive days during July and August was assumed for estimating future peak demand water needs to provide conservative estimates of future needs.
- Of the total amount of water used by the suppliers, 50 percent on an average annual basis is assumed to be consumed (lost to the hydrologic system by evapotranspiration). It is assumed that the remaining 50 percent of the water used by the suppliers returns to the hydrologic system.
- It is assumed that ground water is physically available for future needs of the suppliers, subject to provisions of the Scenic Waterway Act and protection of senior water rights. All new permits for additional ground water to supply future needs of the suppliers will require mitigation under OAR 690-505.

1 PURPOSE

The Deschutes Water Alliance (DWA) is investing in several water resources management provisions for the upper Deschutes Basin. One of the key provisions is to provide reliable and safe water supply for the region's future agriculture and municipal needs taking into account sustained economic viability considering growth, urbanization and related effects on water resources.

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2 WATER SUPPLIERS WITHIN UGBs

2.1 Central Oregon Cities Organization

The Central Oregon Cities Organization (COCO) is a forum for collaboration between the regional urban water suppliers with the goal to work on legislative issues on the State and Federal level that impact the combined cities of Central Oregon including Bend, Culver, Madras, Metolius, Prineville, Redmond and Sisters. Collaborative efforts between the water suppliers are focused on planning for future water needs, responding to growth issues, development of legislative proposals and implementing education programs. COCO entities together with Avion Water Company and Deschutes Valley Water District comprise the regional urban water suppliers in the upper Deschutes basin. The locations of the suppliers are shown on Figure 1.

Funding for preparation of this paper was initially provided by COCO. Funding to complete the paper was provided by a Water 2025 Program grant administered by the Deschutes Water

Alliance (DWA). The initial work funded by COCO developed summary data reports detailing a complete basin-wide long term water needs analysis. These summaries are intended for water planning by suppliers. The upper basin study area for this report is shown on Figure 2 and includes Crook, Deschutes and Jefferson Counties.

2.2 Relevant Water Supply Considerations

The regional water suppliers have water rights as required by law to appropriate public waters for beneficial use by their customers. Most of these water rights authorize use of ground water for supply purposes. Changing water law relative to new ground water appropriations in the upper basin focused the attention of regional water suppliers on planning for future water needs under these circumstances. In 2003, COCO established a water plan including a specific long term action to provide a "Complete Basin-wide long term water needs analysis (coordinated water-use forecast)". This analysis took into account future water needs, sources of water for these needs and methods of securing additional supply for these needs.

The water needs evaluation was also intended to present the collective needs of the regional suppliers within UGBs in one report that will be incorporated with other DWA planning studies to develop a comprehensive water management program for the upper basin in accordance with DWA goals and objectives.

Surface waters are fully appropriated under existing water rights. Water for future needs of the regional suppliers must be developed through conservation and ground water sources. While conservation will reduce the amount of water needed from new ground water supply, it will not be adequate to fully meet future estimated demand for the regional urban suppliers for uses within the UGBs, although more analysis is needed and is underway by the suppliers. If future water needs exceed the water rights presently held by the suppliers, new ground water rights will be required from the Oregon Water Resources Department (OWRD).

New rules for ground water permits were recently adopted based on provisions of the Scenic Waterway Act of 1970 and conclusions of the U.S. Geological Survey (USGS) and Oregon Water Resources Department (OWRD) study (2001). The study concluded that ground water and surface waters in the upper basin are hydrologically connected, and that ground water pumping can measurably reduce surface water flows. Chapter 690, Division 505 of the Oregon Administrative Rules (OAR) describe the rules requiring mitigation for new ground water permits in the Deschutes Basin groundwater study area (Figure 2). Mitigation is intended to offset ground water pumping effects on surface waters and other senior water rights. Mitigation can be accomplished in several ways. An example is retiring land from irrigation and transferring the surface water rights for irrigation back to the source stream as instream flow. The additional flow is intended to offset ground water pumping impacts on stream flows.

Regional supplier future water demand will depend in large part on ground water sources. Where new ground water permits are required for additional supply, mitigation provisions must be provided for the new permits in accordance with the rules. In this case, regional suppliers must plan for and develop water supply for two purposes: 1) water for needs of their users, and 2) water for mitigation purposes.

The focus of this evaluation is on the regional water supplier within UGBs comprising COCO. However, there are other smaller water suppliers in the upper basin that provide water for "community" purposes. Ground water is used for domestic needs in rural areas without municipal or other water utility service. Most of the rural domestic demand is classified as an exempt use by the OWRD. Exempt use means water right permits are not required if domestic use is less than 15,000 gallons per day and irrigation is less than one-half acre, or commercial use is less than 5,000 gallons per day. In addition, exempt wells do not currently have to mitigate for their ground water withdrawals. Future policy discussion regarding the groundwater mitigation program may need to consider how to address this issue.

Demand from water suppliers within UGBs and exempt uses mentioned above do not represent the full extent of demand over the next 20 years. Additional supply for potential future needs was also considered. Several destination resorts are in the development and planning stages in the upper basin. Water needs for a number of these is accounted for under pending quasi-municipal groundwater applications; however, development of other future resorts is possible. Demand for new ground water supply for future potential resorts and other potential uses were also considered in this report.

2.3 Methods

Future water needs of the regional urban suppliers were estimated using population projections and amounts of water use in gallons per person per day (gallons per capita per day-GPCD). Population projections used for this assessment are based on information provided by the water suppliers, Portland State University Population Research Center and Deschutes County Coordinated Population Forecast 2000 through 2025. Water use data for each supplier was analyzed to determine rates of use for peak day, average day and average winter day demand in terms of gallons per capita per day (GPCD). The GPCD measure of demand rate is convenient for use with population numbers to estimate future water needs. Correlations between population and GPCD were used to estimate future water demand.

Water rights and permits presently held by the water suppliers were analyzed to determine how much of the estimated future demand could be supplied by these rights and permits. The estimated future water demand that exceeds existing rights represents additional water supply needs. Water demand increases with population growth. Increased water demand was estimated with projected population growth rates and compared with water availability under existing water rights to estimate when respective suppliers need additional supply over the next 20 years.

Demand for water users other than urban suppliers was determined from records of pending ground water permit applications subject to mitigation rules on file at the Oregon Water Resources Department. This data applies to all pending permits as of September 2, 2005. Mitigation demand and estimated time frame for acquisition of mitigation supply were estimated from the pending permit data.

Ground water availability was assessed by evaluation of recent USGS and OWRD reports on ground water hydrology of the upper basin. Conservation potential was assessed by review of programs conducted by other municipalities in the nation recognized for their results and by

evaluation of conservation programs being implemented by the basin water suppliers. The amount of potential conservation savings was compared to future demand estimates to determine how much of the future needs may require new supply under additional water rights. Mitigation alternatives were assessed according to criteria that accounts for regulatory compliance, cost-effectiveness and environmental factors.

3 POPULATION TRENDS & PROJECTIONS

The purpose of population analysis was to forecast population growth for each of the water supplier within UGBss up to 2025. Water needs increase with increasing populations served by the water suppliers; therefore, estimates of future populations to be served provide a basis for estimating future water demand.

The population analysis was based on available information from a number of sources including water supplier water management and conservation plans (WMCP), the Portland State University Population Research Center and the updated Deschutes County 2000-2025 Coordinated Population Forecast (August 2004). Available population forecasts generally extended to the year 2020. The population forecasts were used for this assessment, without manipulation or alteration, to their future projection dates (i.e., 2020 in several cases). Extension of the forecast period to 2025 was necessary in several cases. Additional analyses and generation of population growth rate curves were required to extend existing forecasts to 2025.

3.1 General Considerations & Approach

Using the available historic data and forecasts, linear forecast analyses were made using a "best fit" line on the annual data points. Realizing that forecasting 20 years into the future can be highly speculative, a ten percent plus or minus deviation was applied to all growth rate curves. "Best fit" graphs of population projections for each water supplier area shown on Figures 3 through 10.

3.2 Results Summary

The population forecasts for each water supplier within UGBs to the year 2025 are summarized below in Table 1.

Table 1. Forecast Population Summary

Urban Water Supplier	2025 Population Forecast Range		
	Low	Med	High
Bend	N/A	75,516	N/A
Avion	52,533	53,051	53,573
Redmond	40,269	45,724	52,145
Sisters	2,996	3,747	3,597
Madras	7,823	8,302	8,841
Culver	1,224	1,299	1,383
Metolius	1,136	1,206	1,284
Prineville	16,397	17,099	17,922

NOTE: Bend and Avion population forecasts reflect only the population within each water service boundary and not overall population growth forecast.

4 WATER SUPPLIERS WITHIN UGBs-POPULATION FORECASTS

4.1 Avion Water Company

The population analysis was based on available forecast information provided by the Avion Water Company (Avion), Portland State University Population Research Center and Deschutes County 2005-2025 Coordinated, Updated Forecast (August 2004). Available population forecasts for Avion extend to the year 2020 and 2025.

The results of the population forecasts for Avion are discussed below. A population forecast graph for Avion is shown on Figure 3 in the appendix of this paper. Avion used a population growth rate of 5 percent annually to develop its Water Management and Conservation Plan (WMCP). The 5 percent growth rate was used to forecast population increases in the Avion service area to the year 2020.

The Avion service area includes a small overlap with the City of Bend Urban Growth Boundary (UGB). The Avion service area extends several miles east of Bend, to the Powell Butte area and potential for Avion to increase its service area in the rural areas is much greater than for the City of Bend. While the rural service area is quite large, the population density in rural areas is less than within the City of Bend's UGB.

Extension of Avion population forecasts from the year 2020 to 2025 was based on an annual growth rate of 2 percent. A deviation allowance of plus 10 and minus 10 percent brackets estimated growth rates between 1.8 and 2.2 percent for the extended period.

The 2 percent growth rate is suggested by Deschutes County as an average county-wide future growth rate to the year 2025. Although Avion has experienced growth rates at more than twice this pace over the last several years, it is not reasonable to expect a 5-plus percent growth rate to continue indefinitely. While it is possible that a higher growth rate could continue, a long-term growth rate of 2 percent is considered more appropriate over the long run for purposes of this paper.

Figure 3 illustrates two different population forecast analyses: 1) analysis using the Avion WMCP forecast to the year 2020 based on a 5 percent growth rate and 2) analysis based on a 2 percent growth rate forecast by Deschutes County, beyond the year 2020.

The projected population forecast based on the 5 percent Avion rate to 2020 and 2 percent County rate beyond the year 2020 is summarized in Table 2. Table 2 also shows forecasts based on a 10 percent deviation above and below the County rate (2.2 percent and 1.8 percent) and are represented as high and low in the table. Population forecasts apply only to populations inside the Avion water service boundary and represent the 2025 forecasted population in Figure 3.

Table 2. Avion Population 2025 Forecast

2025 Population Forecast Range		
Low	**Med**	**High**
52,533	53,051	53,573

The linear forecast shows a lower population forecast at 2025 of approximately 52,000 (Figure 3). For comparison, if population forecasts were made based on a continued growth rate of 5 percent beyond 2020 to the year 2025, estimated 2025 population in the Avion service area would be 61,325. This forecast exceeds the City of Bend forecast and likely overestimates the population potential for rural areas served by Avion. Therefore, for purposes of this assessment, the population forecasts for Avion beyond 2020 are based on the 2 percent growth rate for estimating future water demand.

4.2 City of Bend

4.2.1 The City of Bend Service Area Population

The City of Bend provided three sets of population forecasts performed by different entities for different periods. For purposes of this analysis, the updated Deschutes County Coordinated Population Forecast 2000 through 2025 and the analysis contained in the City of Bend's Water Management and Conservation Plan (WMCP) were used to forecast population growth to the year 2025.

The population forecast contained in the City of Bend's WMCP contained the same data as in the County Forecast; however it is necessary to adjust the forecasts to reflect the population that would be served inside the City of Bend's water service area. Population forecasts for the City of Bend are based on an annual growth rate of 2 percent with a plus or minus 10 percent deviation allowance of 1.8 percent to 2.2 percent. The 2 percent growth rate is the suggested growth rate in the County Forecast. In the last 10 years the annual growth for the City of Bend has exceeded this by more than double nearly on an annual basis.

Figure 4 shows two different population forecast analyses. The analysis with the higher forecasted population growth is based on the County Forecast for the City of Bend. The analysis with the lower forecasted population is based on the Bend WMCP population within the City's water service area. The difference in population could be served by other local water entities such as Avion and the Roats Water Company. For purposes of clarity, the County Forecast will be discussed first, followed by the Bend WMCP forecast.

The Bend WMCP population forecast assumed that the City of Bend water service area would provide water to 70 percent of population growth forecasted by the County. Therefore, the lower population forecast shown on the attached graph (Figure 4) identifies populations that are 70 percent of those forecasted by the County. This 70 percent estimate appears to be reasonable based on the size of the City of Bend and Avion Water Company service areas.

Based on a 2 percent longer term growth rate utilized in the County forecast and the Bend WMCP, the population for the City of Bend water service area in the year 2025 is estimated at 75,516. The linear growth rate projection identifies the same population for the year 2025. Since these numbers are being used for the City's WMCP, a 10 percent plus or minus growth rate deviation allowance was not applied to the estimates in this assessment. Table 3 summarizes the population forecast for Bend.

Table 3. Bend Population 2025 Forecast

2025 Population Forecast Range		
Low	**Med**	**High**
N/A	75,516	N/A

4.3 Deschutes Valley Water District

4.3.1 City of Culver

Water is supplied to the City of Culver by the Deschutes Valley Water District (DVWD), headquartered in Madras. Population forecasts for the Culver were based on the historical growth rates from 1985 to 2003, which are available in the DVWD Water Management and Conservation Plan (WMCP).

Historical data indicates Culver experienced growth at rates of 1 to 2 percent annually with the exception of a short period in the late 1990's when growth increased to approximately 5 percent. As a result, we have projected our forecast populations based on a 2 percent growth rate.

Figure 5 shows the historical growth rates, forecasted growth rate of 2 percent with a plus or minus 10 percent deviation allowance. The 2 percent growth rate was used to forecast population to the year 2025. The population forecast for the City of Culver is shown in Table 4 with a 10 percent plus or minus deviation on forecast numbers (High and Low).

Table 4. Culver Population 2025 Forecast

2025 Population Forecast Range		
Low	**Med**	**High**
1,224	1,299	1,383

4.3.2 City of Madras

Water is supplied to the City of Madras by the Deschutes Valley Water District (DVWD). Population forecasts for Madras were based on the historical growth rates from 1985 to 2003 provided in the DVWD Water Management and Conservation Plan (WMCP).

Historical data indicates Madras experienced growth at a rate exceeding 5 percent from 1985 to 1990. Growth decreased to about 3.5 to 4 percent from 1991 to 1999. Growth has decreased further to less than 2 percent in recent years.

Discussions with City of Madras planning staff indicated that a growth rate of 3.5 to 4 percent is more in line with their expectations for future growth. This is due in part to concentrated efforts by Madras to bring development and industry into the area considering scenic views and closer proximity to Portland than other areas such as Bend. A new corrections facility is being built in Madras and will bring additional employment. Considering City staff input and concentrated efforts to attract development and industry, population forecasts for this assessment were based on a varying growth rate of 4 percent through 2015, 3 percent from 2015 to 2020 and 2 percent beyond 2020.

Figure 6 shows population forecasts based on varying rates and includes a forecast based on the lower annual growth rate of 2 percent with plus or minus 10 percent deviation allowance. The varying growth rate was used to estimate future water demands of the City. The results are shown in Table 5.

Table 5. Madras Population 2025 Forecast

2025 Population Forecast Range		
Low	**Med**	**High**
9,910	10,607	11,004

4.3.3 Metolius Area Population

Water is also supplied to the Metolius community by the Deschutes Valley Water District (DVWD). Population forecasts for Metolius were based on historical growth rates from 1985 to 2003. These were supplied in the DVWD Water Management and Conservation Plan (WMCP).

Historical growth data reflect minimal growth in Metolius from 1985 to 1990. The growth rate since 1990 increased to 3 to 5 percent, dropping to just over 2 percent over the last few years. An overall 2 percent growth rate was assumed for Metolius to the year 2025.

Figure 7 shows the historical growth rates along with the 2 percent rate used for the population forecast to the year 2025. The population forecast based on a 2 percent growth rate, with plus or minus 10 percent deviation (High and Low) allowance is shown in Table 6. The 2 percent population growth rate was used to estimate future water demands for Metolius.

Table 6. Metolius Population 2025 Forecast

2025 Population Forecast Range		
Low	**Med**	**High**
1,136	1,206	1,284

4.3.4 City of Prineville

The Prineville population forecast presented in its Water Management and Conservation Plan (WMCP) fits reasonably well with historic trends. Historic growth ranged from 2 to 3 percent per year from 1990 to 2000, increasing to 4 to 5 percent since 2000. It is possible that growth rates may be elevated in the future due to affordability of land and homes and close proximity to Redmond and Bend.

Figure 8 shows the projected growth rate based on PSU and Prineville forecasts to the year 2020. The plotted growth rate is basically linear; however, due to the sustained growth rate of more than 2 percent and affordability factors, a growth rate of 3 percent is assumed to be more reasonable for population forecasting. Therefore, the 3 percent growth rate was used to forecast population growth from 2020 to 2025. Table 7 shows population projections for the 3 percent rate with a 10 percent plus or minus deviation (High and Low) allowance to the year 2025.

Table 7. Prineville Population 2025 Forecast

2025 Population Forecast Range		
Low	**Med**	**High**
16,397	17,099	17,922

4.3.5 City of Redmond

Population forecasts for the City of Redmond to the year 2025 are based entirely on the County Forecast. The County Forecast for Redmond was based on a simple exponential growth curve of 3.97 percent out to the year 2025.

A more aggressive population growth rate is justifiable for Redmond considering relatively high potential for commercial and industrial zoning, low cost, affordable housing and close proximity to Bend. City planners believe an aggressive growth rate is a better representation of the future population to the year 2025 than the countywide growth rate of 2 percent.

Figure 9 shows the continued growth rate of 3.97 percent. The 3.97 percent rate was used to evaluate future water supply demand for Redmond. Population forecasts based on this rate with a 10 percent plus or minus deviation allowance (High and Low) are shown in Table 8.

Table 8. Redmond Population 2025 Forecast

2025 Population Forecast Range		
Low	**Med**	**High**
40,269	45,724	52,145

4.3.6 City of Sisters

Population forecasts for the City of Sisters were provided its Water Management and Conservation Plan (WMCP) and the County forecast. The forecasts provided in the WMCP were made to the year 2025 based on the annual number of issued building permits. A projected growth rate of 3.13 percent is suggested for Sisters in the County Forecast.

Figure 10 shows the 3.13 percent growth rate projected to the year 2025 with a plus or minus 10 percent growth rate deviation allowance. Table 9 shows population projections for the 3.13 percent rate, with a 10 percent plus or minus deviation (High and Low) for the year 2025.

Table 9.. Sisters Population 2025 Forecast

2025 Population Forecast Range		
Low	**Med**	**High**
2,996	3,747	3,597

The 3.13 percent growth rate was used to estimate future water demand for the City of Sisters.

5 CONSIDERATIONS AND METHODS IN ESTIMATING FUTURE WATER DEMAND

5.1 Relationships Between Population and Water Demand

Population projections provide indications of potential future population numbers in the upper basin. Water demand is directly related to population; therefore, useful relationships can be established between population and water demand for estimating future demand. These relationships are often used for water supply planning by public facilities and are frequently expressed in terms of gallons of water use per person per day, or gallons per capita per day (GPCD). Population and per capita water demand for the water supplier within UGBs are available and can be used to estimate future water demand.

5.2 Per Capita Water Demand

Water demands for each water supplier within UGBs have essentially three principal components: 1) residential, 2) commercial (including parks and schools) and 3) unaccounted for water. Unaccounted for water includes water distribution system leaks, water theft and water use to ensure water quality. Both residential and commercial water demands can be broken down further based on housing density (i.e. large lot zoning verses multi family verses single family) and types of commercial use (i.e. hotels, schools, industry, etc.). However, for purposes of forecasting, it is difficult to predict the types of future commercial and industrial development and how politics and urban planning will affect future residential zoning. Even if these could be determined, other factors influencing potential demand such as future leakage due to aging systems is difficult to predict.

Although the three principal components of water demand are all important at the local level for infrastructure planning, it is not as critical to understand them separately for purposes of basin-wide water use planning. Per capita water demand data based on correlations between population and total system water use (including the three principal demand components) are available for the water suppliers within UGBs. Per capita demand is often used by public suppliers for future water supply planning. The three principal demand components were therefore not analyzed separately for each water supplier. Per capita water use data presented in water management and conservation plans for the water suppliers were not modified in this analysis and were used as reported, along with population projections, to forecast future water demands.

Water suppliers that did not provide a breakdown of daily system water use on a per capita basis did provide total system demand or total diversions. In this case, the total system demand was divided by existing population for each month. Based on the monthly per capita usage, the winter average, the daily average and the peak monthly average were determined. It is important to realize that the peak monthly average may be different than the peak day or maximum use.

Per capita water use was applied to projected future populations to estimate the future water demand for average winter, average daily and average peak conditions. These estimates were compared to existing water rights for each supplier to estimate potential timing for new water right permits and capacity expansion.

5.3 Patterns of Annual Water Use

While it is not critical to separately evaluate the four main water demands to understand total future system water demands, it is critical to consider seasonal water use for each supplier. Water use varies throughout the year due to seasonal climate changes (i.e. summer vs winter). Water use also varies according to daily demand cycles; however, focus was maintained on seasonal variations for demand analysis, recognizing that variations due to daily demand cycles exist within the broader water demand values.

Winter demand is typically the lowest and represents the total system demand during the normal winter months, November through March. Winter demand is typically for indoor water use only, with very little if any outdoor use. Peak demands were determined for the short-duration, peak water use periods during the summer months.

In general, water right holders do not use the maximum rate of water use authorized by a year round water right every day of the year. In some cases, commercial and industrial uses are exceptions to this general statement. In most cases, including water suppliers within UGBs, water use over the year varies according to climate and seasonal demand. Figure 11 illustrates a general pattern of year round water use under a water right. Maximum water use occurs during hotter periods of summer. Minimum use occurs during winter. Water rights are obtained with a maximum authorized rate of water use to provide sufficient supply for peak demand. Water use during off-peak periods, including winter, is well below the maximum rate of use authorized by the water right.

Comparison of Figures 11 and 12 also illustrates the contrast between future additional water needs for the urban water suppliers with existing water rights and water needs for other new water users with new year-round needs. The urban suppliers within UGBs need additional water only for increases in short term peak summer demand (Figure 11). Needs for new ground water supply for future developments depends on whether developments are sited on irrigated or dry lands, and whether they are sited near existing irrigation delivery systems. It is possible that some developments will utilize existing surface water rights to meet irrigation demand, while using groundwater to meet domestic and lawn demand, thereby reducing the need for new ground water supply. It is also possible that other future developments will have no access to existing water rights and will depend totally on new ground water supply.

If new water rights must be obtained for water supply, the annual volume of demand for new users could be large relative to future needs in excess of the water rights presently held by the regional suppliers within UGBs. This new potential demand volume is represented by the blue area in Figure 12. Many residential development projects in rural areas, including destination resorts, outside UGB service areas are in this category of new water users. Water use by these potential future developments will also vary with seasons over the year and will be similar to most other water uses illustrated above. The general pattern of annual water use under a new permit is illustrated in Figure 12.

5.4 Existing Water Rights & Timing of Additional Supply

The water suppliers hold water rights issued by the Oregon Water Resources Department. The maximum authorized rate of use is stated on water right permits and certificates. The authorized rate of use is usually described in terms of cubic feet per second. If the maximum authorized rate on a water right will be exceeded, a new water right is required for use of the additional water. Estimates were made to determine when new water rights need to be obtained by the water suppliers based on review of existing water rights.

6 WATER SUPPLIERS WITHIN UGBs - FUTURE WATER DEMAND

6.1 Water Needs for Peak Summer Demand

Peak summer demand will exceed water rights presently held by of some of the water suppliers within UGBs at various times within the next 20 years. Existing water rights will be exceeded by short-term peak summer demand in the near term for some suppliers and in the longer term for others. Average day and winter demand for all of the water suppliers will most likely remain within the water rights presently held by most suppliers until beyond 2025. Water supply planning and development by the water suppliers within UGBs should therefore focus on future short term, peak summer demand.

6.2 Patterns of Annual Water Use by Water suppliers within UGBs

Additional water will be needed by the water suppliers within UGBs only for future short term peak demand. This limited need reflects a basic pattern of year round water use by urban water

suppliers. Figure 19 illustrates the pattern of water use for growing urban water suppliers. The full amount of water rights held by the suppliers is not used day to day on a year round basis. Figure 19 illustrates that average daily winter demand is well below the maximum rate of use authorized by water rights. Short term peak demand during hotter periods of summer approaches, or can reach the maximum rate of water use authorized by water rights. Urban water suppliers are subject to population growth and increasing water demand in contrast to many other water users. Increasing water demand can ultimately exceed maximum rates of water use allowed by existing water rights. Figure 19 shows that as population growth and water demand increase over time, peak summer demand will be first to exceed existing water rights, while average day and average winter day demands remain well within amounts authorized by existing water rights. Additional water rights are needed in the near-term only for peak demands that exceed existing rights.

6.3 Timing of Future Water Needs

Water demand graphs are presented for each water supplier on Figures 13 through 18. These graphs show estimated average peak demand, average daily demand and average winter daily demand to the year 2025 for each supplier. The graphs also show the maximum rate of water use authorized by water rights presently held by each water supplier.

Estimated future peak demand from the demand graphs for each supplier is shown in Table 10 for the year 2025. The estimated time when existing water rights will be exceeded by peak demand was determined from the intersection between existing water rights and water demand shown on the demand graphs (Figures 13 through 18).

Table 10. Estimated Future Peak Demand

Water Supplier	Range of Total System Demands in MGD Year When Projected Peak Demands Exceed Existing Water Rights	Average 2025 Peak Daily Demand (MGD)
Bend	2007 – 2012	46.47
Avion	2012	26.9
Redmond	2009	25.19
Sisters	2025	3.43
Deschutes Valley Water District	2042	11.77
Prineville	2007	8.74
	TOTAL	**122.5**

Future peak demand estimates indicate that Avion Water Company, City of Bend and City of Redmond need additional water rights in the time frame 2007 to 2012. Prineville also needs additional water rights in approximately 2007 if the City plans to use ground water (Prineville also has surface water rights, which if used, would extend the time for new permits to about 2033). The table also shows that total average peak water supply needs, including existing water rights, for the regional urban and major private water suppliers could reach 122.5 MGD by 2025.

The estimated additional water right needs for the water suppliers were determined by comparing estimated flow rates for future peak demand with maximum authorized flow rates under existing water rights held by the suppliers. The water demand graphs on Figures 13 through 18 show

these relationships. The difference between future peak demand flow rates and rates authorized under existing water rights indicates the amount of additional flows needed under new water rights to the year 2025. The amount of these additional flows are shown in Table 11 in units of millions of gallons per day (MGD) and cubic feet per second (CFS).

Table 11. Projected 2025 Additional Needed Flows

SUPPLIER	Peak Rate Under Existing Water Right (MGD)	Average 2025 Daily Peak Demand Flow Rate (MGD)	Additional Flow Rate Need (MGD)	Additional Flow Rate Need (CFS)	Additional Volume Need (acre-feet)
Bend	36.2	46.47	10.27	15.89	1,416
Avion	16.27	26.9	10.63	16.44	1,465
Redmond	12.84	25.19	12.35	19.11	1,703
Sisters	3.31	3.43	0.12	0.19	17
DVWD	16.55	11.77	0	0	0
Prineville	5.24	8.74	3.5	5.48	488
TOTALS	**90.41**	**122.5**	**36.87**	**56.92**	**5,089**

Table 11 indicates that Avion, Bend, Prineville, Sisters and Redmond need a combined total of 36.87 MGD in new water rights by the year 2025. Zeros for Deschutes Valley Water District (DVWD) indicate these suppliers could meet future estimated demand to 2025 with their existing water rights.

6.4 Estimated Water Demand Relative to Existing Water Rights

Figure 19 illustrates patterns of total estimated year round water use by all of the water suppliers within UGBs for the years 2005 and 2025. Patterns of water use are reflected by variations in seasonal demand. Maximum water demand is during summer and minimum demand is during winter.

The annual water demand pattern for the year 2005 shown on Figure 19 indicates total water use by all of the urban suppliers is within the total amount of water rights held by the suppliers at that time. No additional supply is required for the year 2005. Maximum demand is for peak summer water needs, generally during July and August. The total annual volume of water beneath the 2005 water use graph represents the amount actually pumped by all urban water suppliers in 2005. The total pumped volume in 2005 was about 39,800 acre-feet. If the water suppliers pumped their full water rights on a year round basis, they could pump a total annual volume of 95,800 acre-feet, 2.4 times their actual annual water use.

The total estimated future water demand of all water suppliers within UGBs for the year 2025 is also illustrated in Figure 19. The projected 2025 water demand graph indicates that total future peak demand of all suppliers will reach 122.5 MGD, exceeding the total amount of water rights held by all suppliers. Water demand for average winter day and average day uses will remain within existing water rights held by the suppliers. The annual estimated volume of peak water use by all suppliers in 2025 exceeds total existing water rights by about 5,089 acre-feet. The total annual volume of water pumped over the entire year is estimated at approximately 57,400

acre-feet, which is about 60 percent of the total annual volume that could be pumped under existing water rights held by the suppliers.

7 POTENTIAL FUTURE WATER DEMAND OUTSIDE UGBs

Consideration is warranted for potential water needs of future development to the year 2025. This potential water demand would be in addition to the estimated future needs of the water suppliers within UGBs.

7.1 Future Demand Outside UGBs Needing Permits

Estimates of other potential future demand outside UGBs that need permits are based on the following assumptions:

- Additional ground water permits beyond the 200 CFS cap set by the Oregon Water Resources Commission will be granted.
- Five destination resorts located in areas with no available water rights on the project sites (projects will depend completely on new supply).
- A Destination resort is assumed to include the following:

  2-Golf Courses
  1-Hotel
  400-Single Family Homes
  200-Overnight Facilities (Timeshares, Condos, etc.)
  1-Recreation Center
  1-Conference Center
  2-Restaurants
  Water Features / Ponds

- Additional irrigation of 120 acres with new ground water permits.
- Additional group domestic and other miscellaneous uses of 2.5 CFS with new ground water permits.

An assumption was made that five more destination resorts could be developed by the year 2025. Based on the above assumptions, future developments in the basin including new potential destination resorts would create a water demand of approximately 7,890 acre feet. Given consumptive factors for the different uses, the volume of consumed water would be approximately 4,125 acre-feet. Water demands for future potential uses are summarized in Table 12. This is a speculative estimate based on 5 potential future resorts needing to satisfy their entire water supply need from new groundwater rights, 120 acres of new irrigation and additional group domestic uses. As stated previously, it is possible that some developments will utilize existing surface water rights to meet irrigation demand, while using groundwater to meet domestic and lawn demand, thereby reducing the need for new ground water supply.

Table 12. Water Need Based on Other Potential Future Use

Water Use Description	Water Need (acre-feet)
1 Destination Resort	
2 - Golf course 120 ac each = 240 ac @ 3 af / ac	720
1 - Hotel, 50 rooms, 100 beds	25
400 - Single family homes, 500 GPD each	224
200 - Overnight facilities (timeshare, Condos, etc.)	216
1 - Recreation center / Sports facility	78
1 - Conference Center	14
2 - Restaurants, 200 seats	19
Water Features / Ponds, 10 ac	30
SUB-TOTAL x 5 Destination Resorts	**6,630**
Additional Irrigation of 120 ac (120 ac @ 3 af / ac)	360
Additional group domestic & other (2.5 cfs peak with 1.25 cfs annual avg)	900
TOTAL	**7,890**

7.2 Future Demand Outside UGBs Not Needing Permits – Exempt Use

Ground water is also used for domestic needs in rural areas without municipal or other water utility service. Most of the rural domestic demand is classified as an exempt use by the OWRD. Exempt use means water right permits are not required if domestic use is less than 15,000 gallons per day and irrigation is less than one-half acre, or commercial use is less than 5,000 gallons per day. OWRD records indicate approximately 20,000 exempt wells currently exist in Deschutes, Jefferson and Crook Counties. By 2025, it is estimated that the number of exempt wells could grow to 32,000. The estimated total annual water uses for the current and projected (2025) number of exempt wells are described in Table 13. These numbers are based on OWRD estimates of daily usage rates per well of 1,000 gallons per day (GPD), a 40% consumptive factor and 600 new exempt wells per year.

Table 13. Exempt Ground Water Use

	Number of Exempt Wells	Estimated Annual Volume (acre-feet)	Volume of Consumptive Use (acre-feet)
Current Estimate	20,000	22,400	8,960
2025 Estimate	32,000	35,844	14,338
Estimated Future Increase	**12,000**	**13,444**	**5,378**

8 PENDING GROUND WATER PERMIT APPLICATIONS

8.1 Water Suppliers Within UGBs

8.1.1 Requested Rates of Water Use

Several pending permit applications for various types of ground water use are on file with the Oregon Water Resources Department (OWRD). These applications include municipal water use

requests for Bend, Prineville and Redmond, and account for slightly more than their estimated additional water needs to the year 2025 as discussed earlier in this paper.

Table 14 summarizes the estimated future water needs and the amounts of additional water requested by the three urban water suppliers in their permit applications.

Table 14. Estimated 2025 Water Demand Vs Current Permit Applications

SUPPLIER	Current Estimated 2025 Need (CFS)	Permit Application (CFS)	Difference (CFS)
Avion	16.44	15.00	-1.44
Bend	15.89	24.00	8.11
Deschutes Valley Water District	0.00	16.70	16.70
Prineville	5.47	5.57	0.10
Redmond	19.11	75.00	55.89
TOTALS	**56.91**	**136.27**	**79.36**

Redmond plans to amend its permit application to the estimated rate of 17.57 cfs consistent with additional estimated 2025 water needs and their revised population forecasts. Avion has recently been issued permits for 15.00 cfs, 1.44 cfs short of the estimated additional need by 2025. The Deschutes Valley Water District's (DVWD) pending ground water permit application requests a maximum rate of 16.7 cfs. However, this permit is for longer range water supply purposes in contrast to the more near-term needs (2025) of the other suppliers discussed. Table 15 shows revisions accounting for Redmond's reduced permit rate.

Table 15. Revised Water Demand Based On Amended Permit Applications

SUPPLIER	Current Estimated 2025 Need (CFS)	Permit Application (CFS)	Difference (CFS)
Avion	16.44	15.00	-1.44
Bend	15.89	24.00	8.11
Deschutes Valley Water District	0.00	16.70	16.70
Prineville	5.47	5.57	0.10
Redmond	19.11	17.57	-1.54
TOTALS	**56.91**	**78.84**	**21.93**

In summary, water needs for the listed regional urban suppliers to the year 2025 are estimated at 56.91 cfs. Ground water permit applications have already been filed by the listed suppliers for a total water use rate of 78.84 cfs. Table 15 indicates the suppliers have applied for 21.93 cfs more than their total estimated needs by the year 2025. This is a 28 percent deviation from estimated water needs, which is reasonable considering the range of variables that can change future needs. Therefore, the additional 21.93 cfs will be included in estimations of future water needs of the water suppliers within UGBs to the year 2025.

8.1.2 Adjusted Annual Volume Estimate -

Section 6 of this paper explains that estimated future water needs of the water suppliers within UGBs is for increasing peak summer demands. The estimated total volume of additional peak water need based on population growth projections and per capita water use was reported at 5,089 acre-feet were shown in Table 11.

The urban water suppliers have applied for 21.93 cfs more than the estimated total water needs described in Section 6. This additional rate of water use will also supply water for peak demand. Table 16 reflects updated estimates of the annual volume of future water use by the urban suppliers, accounting for the additional 21.93 cfs in pending permits.

Table 16. Adjusted Annual Volume Estimate

SUPPLIER	Pending Permit Application (CFS)	Additional Volume Needed (acre-feet)
Avion[1]	15.00	1,337
Bend[2]	24.00	2,138
Redmond	17.57	1,565
Sisters	0.00	0
DVWD	16.70	1,488
Prineville[3]	5.57	496
TOTALS	**78.84**	**7,025**

Notes:

[1].Estimated needs to the year 2025 were 16.44 cfs. Estimated volume in table is adjusted to rate of 15 cfs requested by Avion on recently issued permits.

[2] Estimated needs to the year 2025 were 15.89 cfs. Estimated volume in table is adjusted to rate of 24 cfs requested by Bend on pending permits.

[3] Estimated needs to the year 2025 were 5.47 cfs. Estimated volume in table is adjusted to rate of 5.57 cfs requested by Prineville on pending permits.

The adjusted annual volume of water that could potentially be used in excess of existing water permits during the peak use period is therefore 7,025 acre-feet based on pending permits. This volume is 1,936 acre-feet greater than the 5,089 acre-feet volume based on estimated 2025 needs described in section 6. It should be noted, however that the DVWD permit is for longer range water supply purposes in contrast to the more near-term needs (2025) of the other suppliers discussed.

8.2 Other Water Users

8.2.1 Requested Water Use Rates

Pending permit applications for other requested ground water uses are summarized in Table 17. The requested rates in CFS are maximum rates of water use proposed on the pending permit applications. It is likely that most of the requested water uses will vary seasonally as illustrated in Figure 12. In this case, the maximum requested rate of use will likely apply during relatively short-term, peak demand periods.

Irrigation uses are typically not year-round and apply only over the spring-summer-fall seasons; however, the pattern of water use is still similar to the pattern shown on Figure 12. Industrial uses could remain relatively constant throughout the year, depending on the type of application. Pond maintenance water is requested as a volume in acre-feet, and is most likely an irrigation season, or spring-summer-fall season use.

Table 17. Other Pending Groundwater Permit Applications

Pending Permit Applications	Requested Rate / Vol (CFS)	Acres of Irrigation (ac)	Estimated Annual Volume (acre-feet)	Volume of Consumptive Use (acre-feet)
Irrigation	13.4695	1,099.50	3,299	1,979
Industrial	1.1220	NA	811	81
Group Domestic	0.2490	NA	90	18
Pond Maintenance	22.1800	NA	22	7
Quasi-Municipal	38.3110	NA	13,844	5,538
TOTALS	**75.3315**	**1,099.50**	**18,066**	**7,623**

NA: Not Applicable
(1) Consumption is 1.8 acre-feet per acre based on OWRD average for irrigation use in the upper Deschutes Basin
(2) Consumption based on average of 10 percent of total annual water use.
(3) Consumption based on average of 20 percent of total annual water use.
(4) Consumption based on average of 32 inches / year and an average pond depth of 4 feet.
(5) Annual volume based on average annual use = ½ of peak use.
(6) Consumption based on average of 40 percent of total annual water use.

8.2.2 Estimated Annual Volume

Table 17 includes a column for consumptive use, which is the estimated amount of the requested water use that would not return to the hydrologic system after use of the water. The annual volume of water use must be calculated to determine the mitigation obligation for the requested ground water permits discussed later in this paper. The annual volume of water use depends on type and patterns of use over the year.

Irrigation water uses authorized by ground water permits are generally issued with an annual seasonal duty (volume allowance) of 3 acre-feet per acre. Permits have been requested for 1,099.5 acres of irrigation, suggesting that the total maximum annual volume of water use could be up to about 3,299 acre-feet.

Industrial water uses can occur year-round. Variations in amounts of use over the year can occur, depending on the type of use and changes in seasonal demand (due to changes in climate or production). It is assumed for this paper that the requested water use rate of 1.122 cfs will be in effect year-round. The annual volume of water use would then be about 811 acre-feet.

Group domestic water uses usually occur year-round. The pattern of year-round use is also similar to Figure 11 with the maximum rate of use in the hotter periods of summer and lower rates of use during winter. Assuming this pattern of use, the total requested rate on pending group domestic permits would need to be sufficient to meet peak summer demand. Analysis of water-use patterns for the regional urban suppliers indicates that peak rates of use are about two times the average rate of use. Assuming a peaking factor of 2.0 on this basis, the average water use would be about half of the requested rate of 0.249 cfs, or 0.1245 cfs. This estimated 0.1245

cfs translates to an annual volume of approximately 90 acre-feet. Pond maintenance water use is requested in terms of annual volume. The total requested volume is 22.18 acre-feet.

9 MITIGATION REQUIREMENTS-

9.1 Impacts of Ground Water Pumping on Surface Waters; Regulatory Requirements

A joint study of ground water resources in the upper Deschutes Basin by the Oregon Water Resources Department (OWRD) and the U.S. Geological Survey (USGS) established hydraulic connection between groundwater and surface water within the Deschutes Groundwater Study Area (Figure 2). The study is presented in the report *"Ground Water Hydrology of the Upper Deschutes Basin, Oregon, Water Resources Investigations Report 00-4162, Portland, Oregon, 2001."* The OWRD has concluded from the study that ground water uses within the study area have potential for substantial interference with surface water rights and will measurably reduce scenic waterway flows unless mitigation is provided in accordance with the Oregon Administrative Rules Chapter 690, Division 505.0600. Ground water permit applications filed with the OWRD after 1995 must therefore account for mitigation requirements in accordance with OAR 690.505.0600.

9.2 Mitigation to Offset Impacts of Ground Water Withdrawals

Mitigation is intended to offset the impacts of ground water withdrawals to surface water flows. Mitigation can be accomplished by obtaining mitigation credits or by implementing a mitigation project that generates and transfers mitigation water to instream use.

A mitigation credit is a unit of measure to account for mitigation water, in acre-feet, made available by a mitigation project. One mitigation credit is one acre-foot of mitigation water. Mitigation credits can be purchased from the Deschutes Water Exchange (the Exchange). The Exchange is a water bank established for managing mitigation credits. Credits obtained through the bank are temporary and can be used for mitigation until permanent credits are developed through other various methods. Mitigation credits are determined and awarded by the OWRD according to OAR 690-521..

Mitigation obligation means the amount of mitigation water, in acre-feet, needed for the use of ground water under a new permit. Mitigation water is water that is legally protected for instream use from implementation of a mitigation project. The amount of mitigation obligation is determined by the OWRD. Mitigation does not apply to the total volume of ground water withdrawn from an aquifer. The mitigation obligation is determined according to the amount of a ground water withdrawal that is actually consumed (consumptive use).

Consumptive use is the OWRD's determination of the amount of a ground water use that does not return to the hydrologic system in the Deschutes Basin. Consumed ground water is water that is lost to the Basin through transpiration, evaporation or movement to another basin. Consumptive use is determined by multiplying a consumptive use factor times the total annual

volume of ground water to be beneficially used under a ground water permit. Consumptive use factors for various types of water use are summarized below.

Type of Use	Consumptive Use Factor
Industrial	10%
Domestic	20%
Storage (evaporation)	32 inches / year
Commercial	15%
General Agriculture	1.8 ac-ft / ac

A consumptive use factor of 40 percent is generally applied by the OWRD to average year-round municipal and quasi-municipal use. This means that the mitigation obligation will be determined as 40 percent of the total annualized ground water appropriation.

9.3 Mitigation Obligation Required for Future Peak Summer Demand

Peak demand needs for water suppliers within UGBs require additional water right permits within the 20-year planning period. The DVWD has submitted permit applications and plans to meet their mitigation obligation by transferring municipal surface water rights instream. The DVWD is therefore not being considered in this mitigation obligation assessment. Mitigation obligations were estimated according to projected future peak demand and according to pending groundwater permits from the water suppliers within UGBs.

Mitigation obligations are calculated by converting estimated flow rates for future peak demand to an equivalent annualized volume of peak water use. The mitigation obligation is based on the amount of used water that is actually consumed. The consumed amount of total annualized water use must therefore be calculated using an appropriate consumptive use factor multiplied by the total annual volume of water used.

The volume of water use is calculated by multiplying the peak flow rate by the time over which the flow rate is required. Therefore, the volume of water used during a peak demand period depends on the length of time peak flows are being delivered. Generally, the peak demand season is during the dry, hotter periods of summer. The total time span for this potential weather condition is generally over an approximate 70-day period from late June through early September. The graph of projected peak water needs by the year 2025 on Figure 19 shows a smooth, rounded curve during the general period of peak summer demand. In reality, peak demand occurs in spikes over short, discontinuous time intervals within this period and the number of peak demand days generally ranges between 14 and 20 days. The mitigation obligation was estimated on the basis of the graphic representation on Figure 19 on the peak volume in excess of existing water rights.

The total annualized volume of water used to meet peak demand by 2025 is about 5,089 acre-feet as shown on Figure 19. The portion of this total volume that is actually consumed is the product of the total volume of water use multiplied by a consumptive use factor.

Average annual consumption for municipal and quasi-municipal use is generally taken at 40 percent based on OWRD criteria. For this paper, the mitigation obligations for the suppliers are based on 50 percent of the peak demand volume. The 50 percent factor is based on all potential water use (industrial, commercial, domestic, storage and general agriculture) and was used as an overall planning average for estimating the potential magnitude of future mitigation requirements. The actual mitigation obligations could vary from estimates herein, depending on future population growth rates and other factors.

9.4 Water Suppliers Within UGBs Mitigation Obligation

Based on a total projected peak water demand of 5,089 acre-feet by 2025 and a consumptive use factor of 0.50 (50 percent consumption), the total volume of water subject to mitigation obligation for all of the water suppliers within UGBs is approximately 2,544 acre-feet per year. Based on this consumptive use the total mitigation obligation would be 1,414 acres. The OWRD awards 1.8 mitigation credits (1 acre-foot = 1 mitigation credit) per acre of irrigation water right. Estimated mitigation obligations for each urban water supplier are summarized in Table 18.

Table 18. Urban Water Supplier Estimated Mitigation Obligation

SUPPLIER	Estimated Peak Annual Volume (acre-feet)	2025 Estimates Volume of Consumptive Use Subject to Mitigation (acre-feet)	Mitigation Obligation[(1)] (acres)
Bend	1,416	708	393
Avion	1,465	732	407
Redmond	1,703	851	473
Sisters	17	9	5
DVWD	0	0	0
Prineville	488	244	136
Total	**5,089**	**2,544**	**1,414**

(1) Based on 1 acre of irrigation water right = 1.8 mitigation credits.

It is important to realize however, that the estimate of mitigation obligation for regional suppliers shown in Table 18 is based on projected future water use in excess of existing water rights. As stated in section 8.1, the water suppliers within UGBs have applied for groundwater permits. Mitigation obligation according to OWRD would therefore be based on these pending permits. When estimating the mitigation obligations for the pending permits, the DVWD is not considered in the evaluation due to the fact that the DVWD plans to transfer portions of its municipal surface water rights to instream use to satisfy their mitigation obligation. Urban water supplier mitigation obligations based on pending permit applications are summarized in Table 19. These estimates are based on peak water use according to pending permit applications in excess of existing water rights.

Table 19. Urban Water Supplier Pending Permit Mitigation Obligation

SUPPLIER	Pending Permits For Which Mitigation Obligation Is Required		
	Estimated Peak Annual Volume (acre-feet)	Volume of Consumptive Use Subject to Mitigation (acre-feet)	Mitigation Obligation[(1)] (acres)
Bend	2,138	1,069	594
Avion	1,337	668	371
Redmond	1,565	783	435
Prineville	496	248	138
Total	**5,536**	**2,768**	**1,538**

Table 19 shows that the total estimated peak water volume would be 5,536 acre-feet. The dark blue area (peak volume) in Figure 19 given pending permits would therefore be 5,536 acre-feet rather than 5,089 acre-feet (based on population forecasts). The volume of water subject to mitigation would be 2,768 acre-feet and the corresponding mitigation obligation would be 1,538 acres. This is 124 acres more than the 1,414 acres of mitigation obligation based on population forecast estimated peak water use.

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9.5 Other User Mitigation Obligation – Projected Water Use

9.5.1 Mitigation Obligation Outside UGBs Not Needing Permits – Exempt Use

Exempt wells do not currently have to mitigate for their ground water withdrawals. An important issue to consider is that if projected exempt well development proceeds at the estimated pace, this use of groundwater will represent an additional estimated annual volume of 13,444 acre-feet. Given consumptive use factors, this would represent approximately 5,378 acre feet of consumptive use annually (Table 13).. Yet, as stated above this demand is not mitigated – landowners are not required to acquire groundwater mitigation.

9.5.2 Mitigation Obligation Outside UGBs Needing Permits

Based on potential other water use demand requiring permits of 7,890 acre-feet by 2025 and consumptive use factors, the total volume of water subject to mitigation obligation for potential other uses is about 4,125 acre-feet per year. Based on this consumptive use the total mitigation obligation would be 2,292 acres. Estimated mitigation obligations for other potential water uses are summarized in Table 20.

Table 20. Potential Other Use Estimated Mitigation Obligation

Water Use	2025 Estimates Estimated Annual Volume (acre-feet)	Volume of Consumptive Use Subject to Mitigation (acre-feet)	Mitigation Obligation[(1)] (acres)
1 Destination Resort			
2 - Golf course 120 ac each = 240 ac @ 3 af / ac	720	360	200
1 - Hotel, 50 rooms, 100 beds	25	13	7
400 - Single family homes, 500 GPD each	224	112	62
200 - Overnight facilities (timeshare, Condos, etc.)	216	108	60
1 - Recreation center / Sports facility	78	39	22
1 - Conference Center	14	7	4
2 - Restaurants, 200 seats	19	10	5
Water Features / Ponds, 10 ac	30	15	8
SUB-TOTAL	1,326	663	368
SUB-TOTAL x 5 Destination Resorts	**6,630**	**3,315**	**1,842**
Additional Irrigation of 120 ac (120 ac @ 3 af / ac)	360	360	200
Additional group domestic & other (2.5 cfs peak with 1.25 cfs annual avg)	900	450	250
TOTALS	**7,890**	**4,125**	**2,292**

(1) Based on 1 acre of irrigation water right = 1.8 mitigation credits.

9.6 Pending Groundwater Permits Mitigation Obligation – Other Uses

Based on pending groundwater permits for other uses, the total estimated annual volume of use is 18,066 acre-feet per year. Based on this volume and consumptive use factors of 50%, 10%, 20%, 32 in / yr and 40% for irrigation, industrial, group domestic, pond maintenance and quasi-municipal respectively, the total volume of water subject to mitigation is about 7,623 acre-feet per year. Based on this consumptive use the total mitigation obligation would be 4,235 acres. Estimated mitigation obligations for pending permits for other uses are summarized in Table 21.

Table 21. Pending Other Permit Mitigation Obligation

Water Use	Estimated Annual Volume (acre-feet)	Volume of Consumptive Use Subject to Mitigation (acre-feet)	Mitigation Obligation[(1)] (acres)
Irrigation	3,299	1,979	1,099
Industrial	811	81	45
Group Domestic	90	18	10
Pond Maintenance	22	7	4
Quasi-Municipal	13,844	5,538	3,077
TOTALS	**18,066**	**7,623**	**4,235**

(1) Based on 1 acre of irrigation water right = 1.8 mitigation credits.

These groundwater permit applications are pending and create a real potential for mitigation obligation. Cursory investigation indicates that many of these permits may not be pursued at the requested rate and suggest artificially created demand. It is probable that the actual permit application rates could be substantially reduced. In this case mitigation obligation needs would also be substantially less.

10 TOTAL FUTURE DEMAND FOR MITIGATION OBLIGATIONS

Ground water is available for the foreseeable future to meet future water supply needs; however, new groundwater permits can be issued only after mitigation obligations have been met. Therefore, water supply is needed for the duel purposes of future demand and mitigation.

Table 22 shows a summary of mitigation obligation acres needed according to the specified uses mentioned above. The mitigation obligation shows the number of acres of irrigation water right that would need to be retired from irrigation and transferred to instream use as mitigation credits. Mitigation obligations for the water suppliers within UGBs are based on the pending permits listed in Table 19.

Table 22. Summary of Mitigation Obligations

Water Use	Estimated Annual Volume (acre-feet)	Volume of Consumptive Use (acre-feet)	Percent of Total Consumptive Use %	Volume of Consumptive Use Subject to Mitigation (acre-feet)	Mitigation Obligation[3] (acres)
Water Suppliers Inside UGBs[1]	17,600	8,800	38.8	2,768	1,538
Pending Groundwater Permits-Other Uses Outside UGB	18,066	7,623	33.6	7,623	4,235
(Destination Resorts, Domestic…) Outside UGBs	7,890	4,125	18.2	4,125	2,292
Projected Exempt Groundwater Uses (exempt wells)[2]	5,378	2,151	9.5	NA	0
TOTALS	**48,934**	**22,699**	**100**	**14,516**	**8,065**

[1] See Figure 19 for details on total consumptive use and volume subject to mitigation

[2] Exempt well consumptive uses are representative of projected new wells in the basin to 2025

[3] Based on 1 acre of irrigation water right = 1.8 mitigation credits.

The total estimated annual water demand out to 2025 for all projected uses in the basin subject to this study is estimated at 48,934 ac-ft. Given consumptive factors for the different uses, the volume of consumed water would be approximately 22,699 acre-feet. The percent of total consumption by each category of water use in the basin is also listed in Table 22.

When irrigation water rights from surface water sources are to be used for mitigation, the OWRD awards 1.8 mitigation credits (1 acre-foot = 1 mitigation credit) per acre of irrigation water right. Other methods can be used to generate mitigation credits. Use of irrigation water rights for this purpose is intended to illustrate how mitigation obligation is determined.

The above estimations of future demand indicates that approximately 8,065 acres of irrigation water rights will fulfill the mitigation obligation for all estimated future uses including regional water suppliers, destination resorts and other potential uses out to the year 2025. Certain regional water suppliers have already obtained 673 acres of irrigation rights that can be used for mitigation credits to satisfy their individual mitigation obligations. This would reduce the total mitigation obligation necessary for water suppliers within UGBs to 865 acres.

Practical opportunities exist for the water suppliers both inside and outside UGBs to obtain mitigation water through irrigation district transactions involving conversion of lands from farm to urban uses. Irrigation district lands with water rights inside the Bend and Redmond UGBs and Urban Reserve Areas (URA) are the most susceptible to development and land use changes which can provide water for mitigation purposes. A more detailed analysis on how these mitigation obligations could be met can be found in the companion DWA report "*Growth, Urbanization and Land Use Change: Impacts on Agriculture and Irrigation Districts in Central Oregon*".

Most of the total existing demand for mitigation credits is estimated to be met over the next 6 years, or by approximately 2012, due to "pent up" demand conditions resulting from legal challenge to the mitigation rules and related delays in issuing new ground water permits. This time frame estimate is based on mitigation obligations of certain regional urban and major private suppliers, and expectations that a significant part of these mitigation needs will be filled in the near-term. The timeframe estimate is also based on expectations that mitigation for other pending uses would also be achieved in the near-term.

Exempt wells do not currently have to mitigate for their ground water withdrawals. An important issue to consider is that if projected exempt well development proceeds at the pace outlined above, this use of groundwater will total 9.5% of total new groundwater demand over the next 20 years. Yet, as noted in Table 22, this demand is not mitigated – landowners are not required to acquire groundwater mitigation. Future policy discussion regarding the groundwater mitigation program may need to consider how to address this issue.

11 MEETING FUTURE DEMAND FOR FUTURE WATER USER NEEDS

11.1 Sources of Water Supply for Future Water User Needs

Ground water is available for the foreseeable future to meet future water supply needs; however, new groundwater permits can be issued only after mitigation obligations have been met. Therefore, water supply is needed for the duel purposes of future demand and mitigation.

Water for projected future needs of the water suppliers within UGBs can be developed from two basic sources:

1) conservation and demand management; and
2) continued augmentation of supply through new source development (ground water).

Surface water sources are not available because surface waters are fully appropriated under existing water rights for other uses. Surface waters are also more prone to water quality issues and related treatment requirements, which tend to be more expensive and stringent than ground water for public water systems.

11.2 Conservation and Demand Management

Water conservation in general, is important for many reasons. A fundamental goal of water conservation on a broad water supply planning scale nationally and internationally is achieving sustainable use of water resources.

The expanding range of cost-effective conservation opportunities coupled with increased emphasis on achieving sustainable use of water resources has lead to more concerted conservation and demand reduction efforts across the U.S., particularly in regions with serious water shortage issues.

The fundamental question to conservation planning on a broad scale becomes how much conservation is enough. An accepted threshold for "enough" conservation is when conservation costs match costs of developing new source supply.

11.2.1 Oregon State Policy on Conservation and Efficient Water Use

The Oregon Water Resources Commission (OWRC) adopted state policy on conservation and efficient water use. Rules to carry out the policy are presented in the Oregon Administrative Rules Chapter 690, Division 86.

Major water suppliers and water users are encouraged by the policy to prepare water management and conservation plans. The policy rules were developed to provide a process to facilitate efficient water use and to facilitate water supply planning that is consistent with capabilities of the water supplier and the OWRD.

The conservation policy stems from a number of factors including:

- Increasingly frequent summer water shortages in many Oregon regions.
- Expanding water needs for municipalities due to population growth
- In-stream flow demand in response to state or federal listings of sensitive, threatened or endangered species that depend on streamflow and water quality.
- The link between healthy ecosystem functions, water quality, recreation and the Oregon economy.

Continued implementation of conservation projects can help restore streamflows, stabilize water supplies and provide for economic development and growth.

11.2.2 Conservation Measures and Securing Future Demand

Water management and conservation plans have been prepared by the water suppliers within UGBs. Conservation activities are also being implemented to various degrees by the water suppliers. Discussions with the water suppliers indicate an overall average demand reduction of 10 to 20 percent is a reasonable approximation of potential conservation benefits. The amount of potential demand reduction can vary significantly, depending on how conservation is implemented.

The City of Bend is evaluating several conservation methods for reducing demand. The City is currently evaluating the use of "Smart Water Application Technology" (smart controllers) methods including satellite-based pager control systems for irrigation. These systems provide localized evapotranspiration information for areas as small as 1 square kilometer and match water plant demand with application. City of Bend evaluations include testing of 50 smart controllers at 29 different sites. Monitoring of water demand based on evapotranspiration data indicates the controllers were not off by more than $1/100^{th}$ of an inch per month. Testing and analysis by the City indicates that average savings of 41% were obtained at test sites with smart controllers. The City of Bend and other cities estimate that these systems can lead to average water savings in outdoor irrigation demand of 20 to 40%.

Bend is presently working with developers in a partnering arrangement to utilize smart controller systems for irrigation in new development projects. The City Council approved a smart controller resolution in 2004 that supports investigation and implementation of conservation technology. The City of Bend is also pursuing grants with the Oregon State University Extension Service for continued investigation of conservation methods.

Water for future needs of the water suppliers can come from two sources: 1) development of new supply from sources, and 2) conservation. Consequently, all water for future needs does not require additional appropriation from ground water sources.

The total estimated water need for future peak summer demand in excess of water rights presently held by the water suppliers is 5,089 acre-feet. Part of this volume requirement can be eliminated by reduced demand through conservation programs. Assuming an average overall range of 10 to 20 percent demand reduction through conservation, the net volume of water required from additional ground water appropriation would be in the range of 4,071 to 4,580 acre-feet. Conservation might reduce dependency on new supply appropriation even further considering that Seattle utilized conservation to meet increasing water needs for 20 consecutive years.

11.2.3 Demand Management

The demand management concept is systematic in design and implementation and provides programs or measures proven to reduce water needs through technical, educational and economic (pricing) means. Conservation programs can be developed and implemented in the context of an overall demand management system.

Demand management brings many advantages to water suppliers. Considerable increases in efficiency of urban water use can be achieved through a guided water demand management program involving water pricing and integration of long-term water supply planning into broader resource planning processes (i.e., integrated resource management). Reduction in demand can also bring the following benefits:

- Energy savings for heating, pumping and treating water.
- Reduced costs of water treatment and distribution system capacity, including capacity of infrastructure for wastewater collection and treatment.

- Reduced capital expenditures due to deferred or downsized new water supply projects.
- Environmental benefits of reduced water withdrawals from streams and aquifers

Other opportunities for reducing demand are available in water-efficient fixtures and appliances (low-flush toilets, washing machines, drip and micro-spray irrigation systems). Availability of new and improved fixtures and appliances at competitive prices is expanding the range of readily available opportunities for demand reduction.

Demand management concepts include shifting water sources for certain municipal needs such as irrigation. For example, it might be possible in some cases to shift irrigation supply during the peak summer season from the principal municipal supply system to other sources, including treated effluent or irrigation districts. Although these concepts appear to be logical solutions for reducing dependency on new supply, the practicality of their use depends on a wide range of physical, social and economic conditions.

The City of Bend considered treated effluent and irrigation district water for irrigation and found that installation of the required distribution infrastructure within developed areas already criss-crossed with utilities, streets and other infrastructure was prohibitive in economic and practical terms. The City has a contract to provide treated effluent at a flow rate of approximately 2.0 MGD to a destination resort development to the east of city limits. This arrangement is practical because the resort development project is in near proximity to Bend's wastewater treatment facility and effluent can be delivered by gravity flow through undeveloped areas with limited pumping requirements.

Opportunities may exist in other cities, depending on proximity to irrigation districts, logistics and physical opportunities for the required infrastructure and water. The proportion of future supply that could be met with conservation measures is related to demand management and investment in new conservation technology and education by basin water suppliers. Although it is possible that these kinds of demand management scenarios could be implemented in conjunction with long-term water management in the upper basin, feasibility of these potential opportunities requires detailed evaluation that is beyond the scope of this report. As in conservation, demand management scenarios can help reduce needs for new supply development. However, they will not preclude the need for developing new supply.

11.3 New Groundwater Source Development

Peak demand for some Bend, Prineville, and Avion are near the maximum flow rates allowed by their water rights. In these cases, implementation of measures to secure additional capacity is required. A first step in this process is to review its presently held water rights and authorized points of appropriation (location of wells). It may be possible to adjust points of appropriation to include permits for which wells are not yet installed to increase capacity for the near term. For example, Bend was faced with a very small cushion between 2003 peak summer demand and maximum appropriation rates allowed by its water rights. Review of Bend's water rights indicated that existing wells could be added to available permits to increase pumping capacity. This approach provided the City with additional time to implement other permit provisions.

Allowing for conservation and potential demand management opportunities, development of new water supply for future supply needs will depend on groundwater sources. Most of the present water supply for the regional urban and major private water suppliers is obtained from groundwater sources.

11.3.1 Groundwater Occurrence

Groundwater is rainfall or runoff created from melting snow or other sources that percolates into the ground, filling voids in underground geologic materials. Underground zones or strata that have sufficient voids to store and readily yield water to wells for water supply are referred to as aquifers. Not all rainfall or water from other sources percolates into the ground. Some of the water evaporates, some is taken up by vegetation and some becomes surface runoff forming creeks and streams.

The proportion of water that becomes groundwater depends largely on the permeability of the ground exposed to water. Soils and geologic formations in the upper Deschutes Basin are volcanic in nature, very young, un-weathered and highly permeable. Combined with heavy annual snow pack in the higher elevations, the permeable materials provide ready access for water to penetrate into the ground and provide an underground water supply that is replenished on an annual basis. Annual replenishment is this manner is referred to as aquifer recharge.

Precipitation and the annual snow pack in the High Cascade Mountain Range and foothill areas are the major sources of natural annual recharge to the aquifer system in the upper Deschutes Basin. These principal recharge areas are located on the west and southwest flanks of the upper basin. Significant natural recharge also occurs in the Paulina Mountains in the south part of the upper basin.

Total average annual groundwater recharge was estimated by the U.S. Geological Survey (USGS) to be about 3.3 million acre-feet. This annual volume equates to an average flow rate of approximately 4,566 cfs, or 2,951 MGD. Water enters the aquifer system year after year; however, it never fills the entire thickness of geologic materials in the upper Basin. As groundwater accumulates in the subsurface formations, it also discharges from the system. Groundwater moves through permeable subsurface formations under the force of gravity from high-elevation recharge areas to low elevation discharge areas. Groundwater discharge occurs as springs or as flow into streams where down cutting of streambeds has intersected the aquifer system.

The Deschutes River between Lower Bridge and Lake Billy Chinook, the lower Crooked River and the Metolius River are major groundwater discharge areas for the upper Basin. Groundwater discharge also accounts for most, if not all of the flow in several other streams including, but not limited to the Fall, Spring and Cultus Rivers in the upper part of the basin, southwest of Bend.

11.3.2 Groundwater Availability

Groundwater is available in the upper Deschutes Basin aquifer system to support the estimated future needs of the water suppliers for the foreseeable future. The current total estimated groundwater removed from the upper basin by water suppliers within UGBs is approximately

39,800 (Figure 19). Assuming a consumption rate of 50 percent for all uses, the current estimated amount of water consumed in the basin by all water suppliers within UGBs is 19,900 acre-feet. This represents 0.60% of the total average annual groundwater recharge of 2.7 million acre-feet estimated by the U.S.G.S. A more detailed analysis of total consumptive use in the basin is presented in the companion DWA report "*Instream Flows in the Deschutes Basin"*.

A rough idea of potential future ground water consumption by water suppliers within UGBs was made in this assessment based on population increase rates estimated from 1995 to 2006 with data from the Deschutes County 2000-2025 Coordinated Population Forecast. Based on the population forecasts presented in this report, the annual volume of water pumped by all regional water suppliers is estimated at 57,400 acre-feet. Assuming a 50 percent consumption rate for all uses, the total estimated amount of consumed water is 28,700 acre-feet. The projected 2025 consumptive use of all water suppliers within UGBs would therefore represent 0.87% of the total annual recharge of 3.3 million acre-feet estimated by the U.S.G.S.

It is important to note that the above percentages only represent the portion of total annual recharge consumed by water suppliers within UGBs. The total consumed amount for all uses would be higher and are presented in the the companion DWA report "*Instream Flows in the Deschutes Basin"*. Nonetheless, while the estimated percentages of future average annual ground water withdrawals are relatively small relative to estimated average annual recharge, the difference does not preclude needs for managing the resource. The mitigation rules have brought basin water suppliers together for initiation of management efforts in the upper basin.

The effects of ground water pumping could not be measured below the confluence of the Deschutes, Crooked and Metolius Rivers at the time the USGS report was published (2001). Capability to measure potential impacts is limited by flow gage measurement techniques with accuracy of plus or minus 5 percent. This range of error applied to an average summer flow rate in the Deschutes River at the Madras gage is about 200 cfs. The estimates of consumptive ground water use discussed above are less than this margin of error; therefore, it is difficult to recognize any measurable influence of pumping on stream flow.

The USGS concludes that pumping effects could be measurable on smaller streams in the upper basin although effects on stream flow cannot be conclusively identified in flow records. Specific examples of potentially susceptible spring-fed streams include Fall River, Indian Ford Creek and Whychus Creek.

Climatic conditions and impacts on ground water discharge also warrant consideration. The estimated amounts of ground water withdrawal and consumption are small when compared to observed natural fluctuations in ground water discharge. The USGS reports natural variation of 1,000 cfs in ground water discharge upstream from Madras due to climate cycles. Although this magnitude of variation masks effects of ground water withdrawals on stream flow, the USGS concludes that effects are present based on geologic and hydrologic analysis.

In summary, the upper basin contains a large supply of ground water with a relatively efficient recharge system driven by precipitation and snow melt, and high degree of water infiltration to the aquifer system through permeable geologic materials. The amount of water in the system is

many orders of magnitude larger than total present ground water consumption and consumption amount estimated for 2025. Constraints on ground water use are potential impacts of withdrawals on stream flow and other senior water rights. These constraints introduced the upper basin to conjunctive management of ground water and surface water resources. The mitigation rules discussed above were adopted to offset these effects. Future ground water withdrawals must account for pumping impacts through the mitigation process.

12 FLOW CONTRIBUTION TOWARD ODFW INSTREAM TARGET FOR MIDDLE DESCHUTES RIVER

The water supplier within UGB mitigation obligation to the year 2025 is estimated at 1,538 acres. To fulfill the mitigation obligation, this acreage of surface water rights must be transferred instream and protected as instream flow. Transfer of 1,538 acres of irrigation rights to instream use could contribute about 31 cfs toward the ODFW flow target of 250 cfs for the middle Deschutes River below Bend.

The total estimate mitigation obligation for all pending ground water permit applications is roughly 4,235 acres. The potential instream flow contribution from this mitigation acreage could add an additional 85 cfs.

It is possible that the net amount of flow protected instream could be somewhat less than the above estimates, depending on OWRD review and confirmation of amounts to be protected. The potential flow amounts can also vary depending on actual mitigation requirements determined by the OWRD.

13 SUMMARY

Water use by the water suppliers within the UGBs varies over the year, similar to most other water uses. The maximum rate of water use is highest during the hotter periods of summer, usually during July and August. Irrigation during this time is the major component of increased water use. An illustration of water use by the suppliers over the year is shown in Figure 19.

Given potential projected population growth rates, increases in peak summer demand rates during the next 20 years will exceed maximum water use rates authorized by existing water rights during short, hot weather periods of summer (usually during July and August). If the projected population growth rates occurred, new water rights would be required only for these short-term peak needs.

Future water needs were estimated with population projections reported by the Coordinated Deschutes County Forecast, Portland State University and in water master plans prepared by the regional suppliers. The estimates reflect the potential magnitude of future needs as a planning benchmark for developing water supply plans in conjunction with DWA objectives.

The total estimated annual water demand out to 2025 for all projected uses in the basin subject to this study is estimated at 48,934 ac-ft. Given consumptive factors for the different uses, the volume of consumed water would be approximately 22,699 acre-feet.

The volume of consumptive use subject to mitigation is estimated at 14,516 acre feet. Exempt wells do not currently have to mitigate for their ground water withdrawals. It is estimated therefore that approximately 8,065 acres would satisfy the mitigation obligation for all potential future demand.

It was estimated that water rights to satisfy urban regional water suppliers within UGBs would be needed for an approximate volume of 5,089 acre-feet to satisfy annual peak short term summer demand. The approximate volume to satisfy annual peak short term summer demand for water suppliers within UGBs based on groundwater permit applications currently on file with OWRD is 5,536 acre-feet. In estimating projected 2025 mitigation obligation requirements, the estimated annual peak volume based on pending permits was used. New water rights for the future peak needs could be obtained incrementally in relatively small amounts over time.

The water suppliers within the UGBs will most likely depend on ground water for additional supply. Based on OWRD mitigation requirements and projected population growth rates, water suppliers within UGBs would need water for future consumptive needs and mitigation. Mitigation is required for the amount of used water that is consumed. Given an annual peak water demand and the volume of consumed water, the mitigation obligation for water suppliers within UGBs is 1,538 acres (based on permit applications).

Irrigation district lands with water rights inside the Bend and Redmond UGBs and Urban Reserve Areas (URA) are the most susceptible to development and land use changes which can provide water for mitigation purposes. Practical opportunities exist for the water suppliers within the UGBs to obtain mitigation water through irrigation district transactions involving conversion of lands from farm to urban uses.

The estimated annual volume of consumption for pending groundwater permits is approximately 7,623 acre-feet. Assuming that surface water irrigation rights will be used for mitigation, about 4,235 acres of irrigation rights would be required to satisfy the mitigation obligation for the existing permit applications.

The estimated total annual ground water demand for other potential future uses including destination resorts is about 7,890 acre-feet. Based on consumptive rates for the various uses, the total area of irrigation rights to satisfy the mitigation obligation is about 2,292 acres.

Current consumptive use of groundwater is estimated at 35,895 AF in the companion DWA report "*Instream Flows in the Deschutes Basin*". Additional needs by the end of the 20-year period to 2025 suggest roughly another 22,699 acre-feet/yr of consumptive use. Total consumptive use of groundwater would then be 58,594 acre-feet/year of a total recharge of 3.3 million acre-feet. Total water use would be 1.8% of annual groundwater flux. Although ground water is physically available to meet future needs, future ground water pumping could measurably reduce stream flows due to hydrologic connectivity between the aquifer and surface waters in the upper basin. Groundwater mitigation provided through leases, transfers and other approved projects would have the intent of reducing consumptive use at the appropriate point of return flow, particularly in the confluence area around Lake Billy Chinook. In other words the increase in consumptive use of groundwater would be offset by a reduction in consumptive use

of surface water. As part of the analysis of an overall basin water management plan these activities and their impacts will be examined further as the requisite surface and groundwater modeling tools are developed and refined.

While surface waters are fully appropriated under existing water rights (mostly irrigation), the water suppliers within the UGBs will most likely depend on ground water and municipal water conservation to meet additional demand. Conservation measures already implemented by water suppliers within UGBs have helped reduce demand, thereby putting off the date at which future supply is required. The proportion of future supply that could be met with conservation measures is related to demand management and investment in new conservation technology and education by basin water suppliers. Conservation alone is not adequate to fully meet future estimated demand for the regional urban suppliers for uses within the UGBs, although more analysis is needed and is underway by the suppliers. In general, it is estimated that conservation can reduce demand on new supply by about 10 to 20 percent on average. Future demand will therefore most likely be met by a combination of municipal water conservation measures and new ground water permits.

14 REFERENCES

USGS, "*Geologic Framework of the Regional Ground-Water Flow System in the Upper Deschutes Basin, Oregon.*". Water Resources Investigation Report 02-4015. 2002

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US Bureau of Reclamation, *"Upper Deschutes River Basin Water Conservation Study, Special Report, Crook, Deschutes, and Jefferson Counties, Oregon"* 1997

APPENDICES