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REPORT ON

GROUNDWATER MODELING OF NEW WATER RIGHT AND TRANSFER APPLICATIONS CITY OF YELM, WASHINGTON

Submitted to:

City of Yelm
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Submitted by:

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List of Acronyms and Abbreviations

ac-ft/yr	acre-feet per year
cfs	cubic feet per second
Ecology	Washington State Department of Ecology
ft/day	feet per day
Golder	Golder Associates Inc.
gpm	gallons per minute
mgd	millions gallons per day
msl	mean sea level
Qgr	Vashon Recessional Outwash
Qga	Vashon Advance Outwash
Qpg	Pre-Vashon Gravel
RM	river mile
sq.ft/day	square feet per day
SSPA	S.S. Papadopoulos and Associates
TQu	Undifferentiated Tertiary
USGS	U.S. Geological Survey
Yelm	City of Yelm

Common Unit Conversions

1 cfs	= 448.9 gpm
1mgd	= 694 gpm
1 acre-feet	= 43,560 sq.ft
1 sq.ft/day	= 7.481 gpd/ft

1.0 INTRODUCTION

1.1 Background

The City of Yelm (Yelm) is considering a water supply development program to support anticipated growth that minimizes hydrologic impacts in the lower Nisqually River watershed. Yelm has several pending water rights applications (both new and transfers) that would permit an increase to their groundwater supply to meet projected future demand.

This report presents a groundwater modeling assessment prepared by Golder Associates Inc. (Golder) to support Yelm's water rights applications to the Washington State Department of Ecology (Ecology). This assessment includes updating the City of Olympia's McAllister Numerical Groundwater Model (the model), and then using the model to simulate five transfer and new appropriation scenarios under which Yelm would meet their 30-year (2036) demand. Figure 1-1 shows the model domain.

Along with Yelm, the cities of Lacey and Olympia are also engaged in a coordinated effort to secure sustainable water supplies while considering the watershed health as a whole. Golder has provided modeling assistance to Lacey, and during the course of the modeling work described in this report, Golder worked collaboratively with Olympia's consultant (S.S. Papadopoulos and Associates [SSPA]) to ensure that the modeling approach was consistent between the cities. This effort is considered necessary to enable model results for Yelm, Lacey and Olympia to be comparatively evaluated and to allow regulators to make decisions on the basis of uniformly developed results.

1.2 Purpose

This report presents the approach, results and conclusions of a series of updates made to the McAllister model by Golder on behalf of the cities of Yelm, Lacey and Olympia. The model was updated in response to meetings held between representatives of the three cities and the Squaxin Indian Tribe in May and June of 2007. The Squaxin Indian Tribe asserted that the original version of the model inadequately represented the Deschutes River and lacked the necessary level of detail to quantitatively assess hydrologic impacts from planned groundwater pumping increases and transfers.

Some additional changes were also identified during a hydrogeologic review of the East Olympia Wellfield area, as part of Olympia's wellhead protection area delineation (Golder, 2007b). Consequently, Golder developed a scope of work to make changes to the model structure and rerun some wellfield pumping scenarios.

1.3 Model History Overview

1.3.1 Initial Model Development and Application

The model was originally developed by the City of Olympia to assess possible hydrologic impacts of a planned 19 million gallons per day (mgd) wellfield, to be located near McAllister Springs (CDM, 2002a; CDM 2002b). Consequently, the model's focus was primarily to represent the hydrologic features in the McAllister area. The main hydrologic features represented by the model include the following:

- The main regional rivers - the Nisqually River (to the east) and the Deschutes River (to the west),

- Several smaller streams that drain directly either to the regional rivers or Puget Sound (such as Woodland Creek);
- Several glacial lakes that are either hydrologically fully-closed (such as Lake St. Clair), or receive water from (and discharge to) surface streams; and
- Natural springs and seeps, notably the spring system located in the upper McAllister Creek area, and side-valley springs along the McAllister Valley bluffs.

The flow or water level in these features is supported in part by discharge from groundwater, and is therefore potentially influenced by changes in groundwater extraction.

1.3.2 Lacey Updates and Simulations

In 2006, Lacey (operating under a Memorandum of Understanding with Olympia) updated the original version of the model to include new hydrologic data (Golder, 2006). Lacey then used the updated model to simulate the effects of a series of water right transfers and new right applications that were submitted to Ecology. The updates included the following:

- Correct annual and monthly pumping rates for Lacey production wells;
- Recent annual and monthly precipitation records;
- Measured McAllister Springs discharge and production rates provided by Olympia;
- Woodland Creek and Eaton Creek discharge data; and
- Improving lake and interconnecting stream water budgets for the three lakes (Hicks, Long and Pattison lakes) and their associated wetlands using Thurston County data.

In addition, some minor changes were made to the model grid to improve computational stability.

1.3.3 Revised Olympia Simulations

Olympia used the same updated version of the model to evaluate the effects of three potential wellfield supply scenarios (HDR/SSPA, 2006). The wellfield arrangement was the same as that represented in the original model and is located about 1 mile south (up-gradient) from McAllister Springs.

1.3.4 Yelm Updates and Simulations

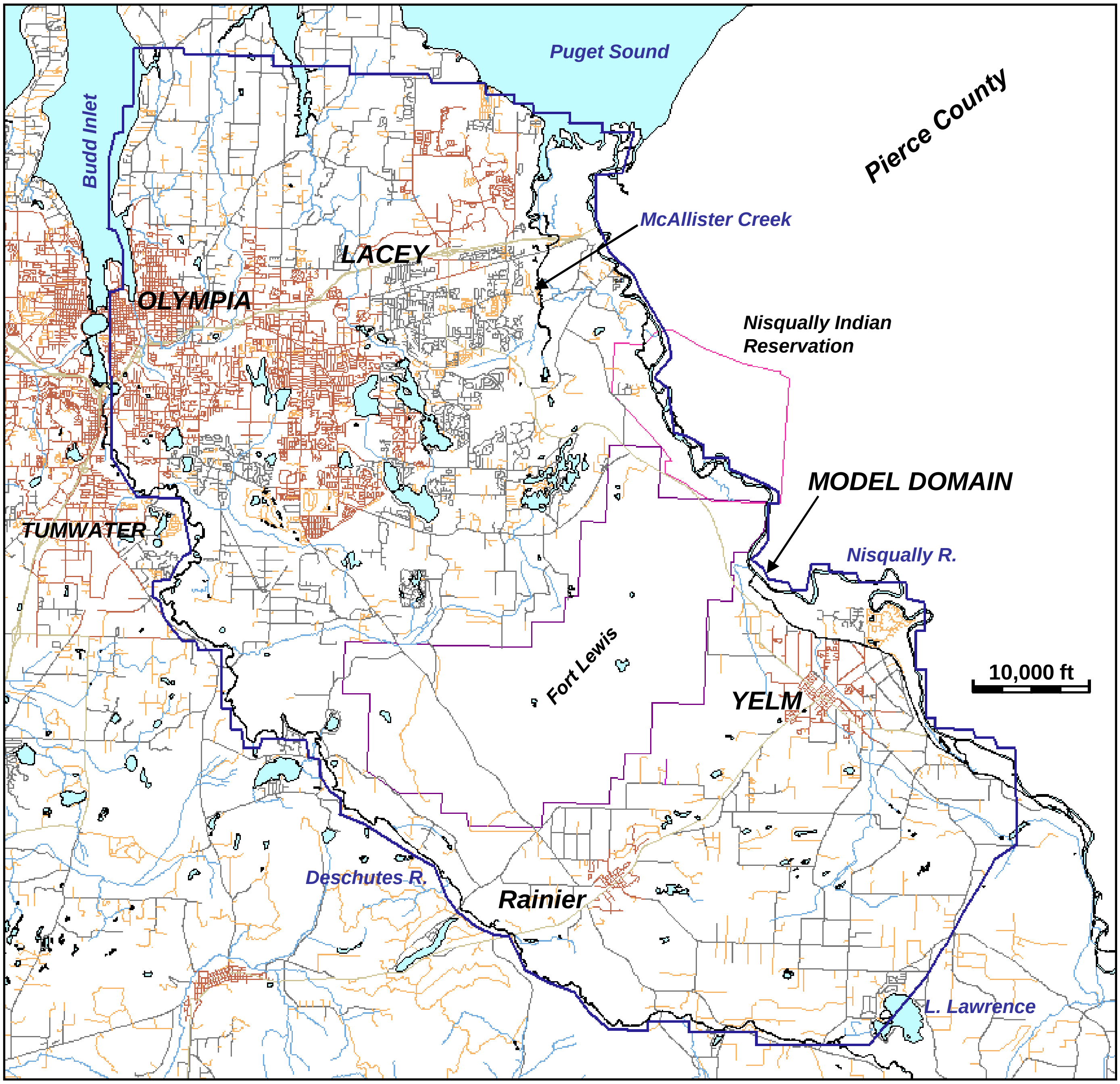
In 2007, Golder updated and improved the model for the City of Yelm area, and used the new version of the model to simulate five long-term groundwater pumping scenarios for the City of Yelm (Golder, 2007b). The changes described in this report were to use this most recent version of the model designed to address the added focus on the Deschutes River system requested by the Squaxin Indian Tribe and additional changes in the East Olympia Wellfield area.

That model received thorough peer review during development, and Ecology accepted the model and its results. The model is therefore an established and best available tool to quantitatively predict groundwater flow conditions and potential hydrologic impacts in the area. The updates were made with the goal of improving the model's ability to represent actual conditions, and have been accepted by reviewers and stakeholders. The version of the model described above was modified to provide greater resolution of the aquifer system in the Yelm area, as described Sections 2.0 and 3.0 of this report.

1.4 Work Process

The modeling effort necessary to quantitatively evaluate Yelm's future pumping involved a series of steps. Each step is summarized below, and is described in detail in subsequent sections of this report.

- Step 1 - Update the existing steady-state version of the model (which represents long-term, average annual conditions) to include new and previously excluded data and hydrogeologic interpretations of conditions.
- Step 2 – Re-run and (if necessary, revise) the existing steady-state and transient (time-varying) calibration runs using the newly updated model.
- Step 3 - Establish a baseline condition (referred to hereafter as the Baseline case), including the best understanding of existing conditions.
- Step 4 - Develop and simulate a series of future groundwater pumping scenarios that meet the 30-year (2038) demand, and calculate hydrologic changes for each case as compared to the Baseline case.
- Step 5 - Conduct a limited sensitivity analysis to determine the model's accuracy for predicting hydrologic impacts.



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TITLE

McAllister Groundwater Model Domain

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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REVIEWED	JS	FILE No.	Sims_figs_port.ppt	FIGURE No.	1-1

2.0 NEW DATA FOR THE DESCHUTES RIVER

2.1 U.S. Geological Survey Flow Records

Golder collected historical flow data recorded at two gages on the Deschutes River that are maintained by the U.S. Geological Survey (USGS). These stations are show on Figure 2-1 and are as follows:

- 12079000 – Deschutes River near Rainier, WA – at river mile (RM) 2.4
http://waterdata.usgs.gov/wa/nwis/uv/?site_no=12079000&PARAmeter_cd=00060,00065

- 12080010 – Deschutes River at E Street Bridge, Tumwater, WA – at RM 25.9
http://waterdata.usgs.gov/wa/nwis/uv/?site_no=12080010&PARAmeter_cd=00060,00065

Although daily records exist for both stations as far back as the late 1940s, no data were available from the USGS web site for several extended periods, most notably during the late 1980s for the Rainier gage. However, the Squaxin Indian Tribe provided synthesized data (based on other gage data) for inclusion in this study (Konovsky, pers comm., 2007b).

Figures 2-2 and 2-3 show the recorded daily flows for the Rainier and E Street Bridge gage from October 1988 to September 2006. Figures 2-4 and 2-5 show the same data sets, but focus on the low flow realm (up to 200 and 400 cubic feet per second (cfs) for the Rainier and E Street gages, respectively). Note that the transient calibration period for the current version of the McAllister model extends from October 1989 to September 2005.

The seasonal low flows for both stations during this period typically were recorded during either September or October (of the subsequent water year), and are shown in Figure 2-6. The net flow increase over this 23.5 mile reach for the respective low flows for each year are shown in Figure 2-7. The summer low flows for the two gages ranged from 19 to 39 (at Rainier) and 48 to 120 (at E Street Bridge) (Figure 2-6). The differences ranged from 26 cfs (in 1994-1995) to 81 cfs (in 1996-1997), with a 16-year average of 46.3 cfs (Figure 2-7).

This low flow increase between the two stations is due to groundwater seepage and surface inflows from tributaries. The major tributaries are as follows:

- Silver Spring Creek – enters from the east at RM 17.4 (Figure 2-1);
- Tempo Lake outfall - from the west at approximately RM 14;
- Spurgeon Creek - from the east at RM 9.2 (Figure 2-1);
- Ayer Creek - from the west at RM 5.6;
- Chambers Creek - from the east at approximately RM 4 (Figure 2-1); and
- An un-named creek - from the west at approximately RM 2.

No permanent flow gages exist on these six tributaries, which makes determining the groundwater seepage component of the total flow very difficult to calculate with any degree of reliability. Only if the surface inflows are zero during low-flow periods can the total flow increase be considered groundwater discharge.

In August 1988, the USGS estimated that the flows at the Rainier and E Street Bridge stations were 35 cfs and 89 cfs, respectively, indicating an increase over the 23.5 mile reach of 54 cfs (Drost, et al. 1999; p.223). The report also provided estimated inflows from three tributaries between the two stations totaling 10.5 cfs. Therefore, the estimated groundwater discharge to the river was 43.5 cfs. However, as the record database indicates that the gage at E Street was not operating in August 1988, the USGS estimated flows should be used cautiously.

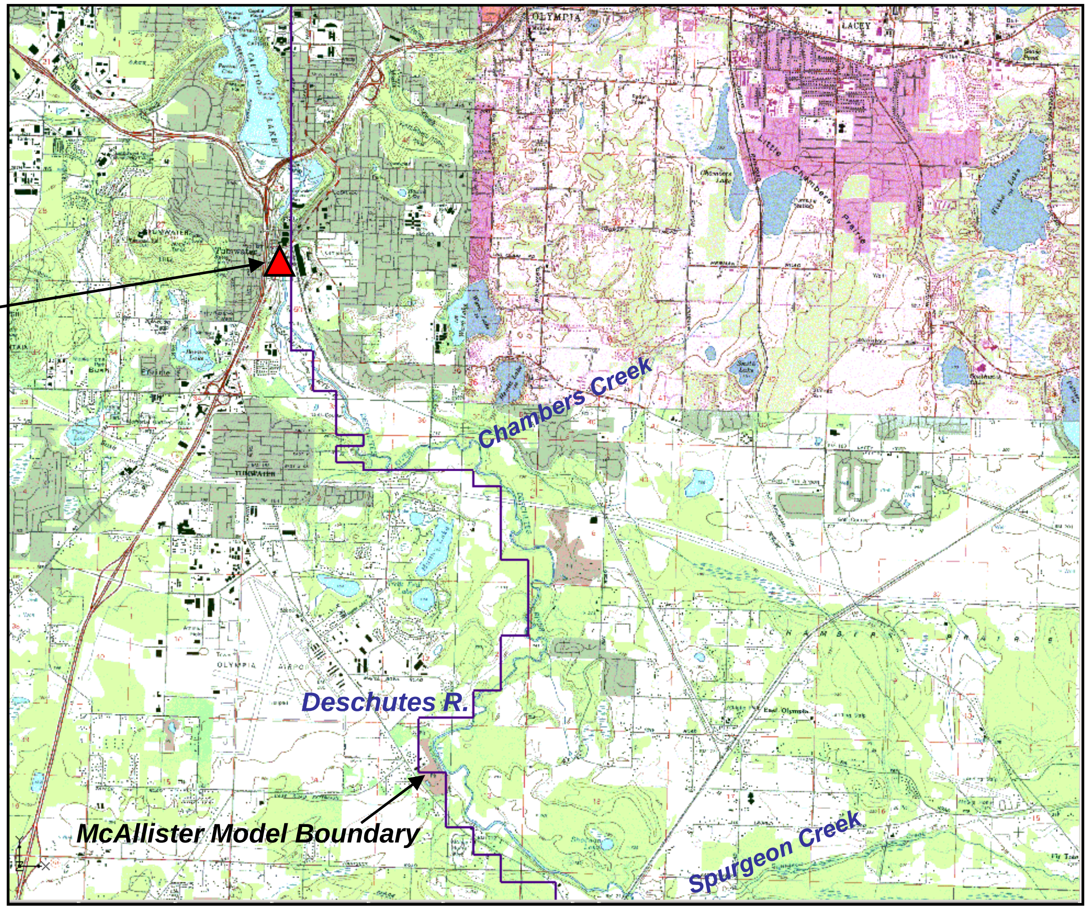
2.2 Washington Sate Dept. of Ecology Study (2003)

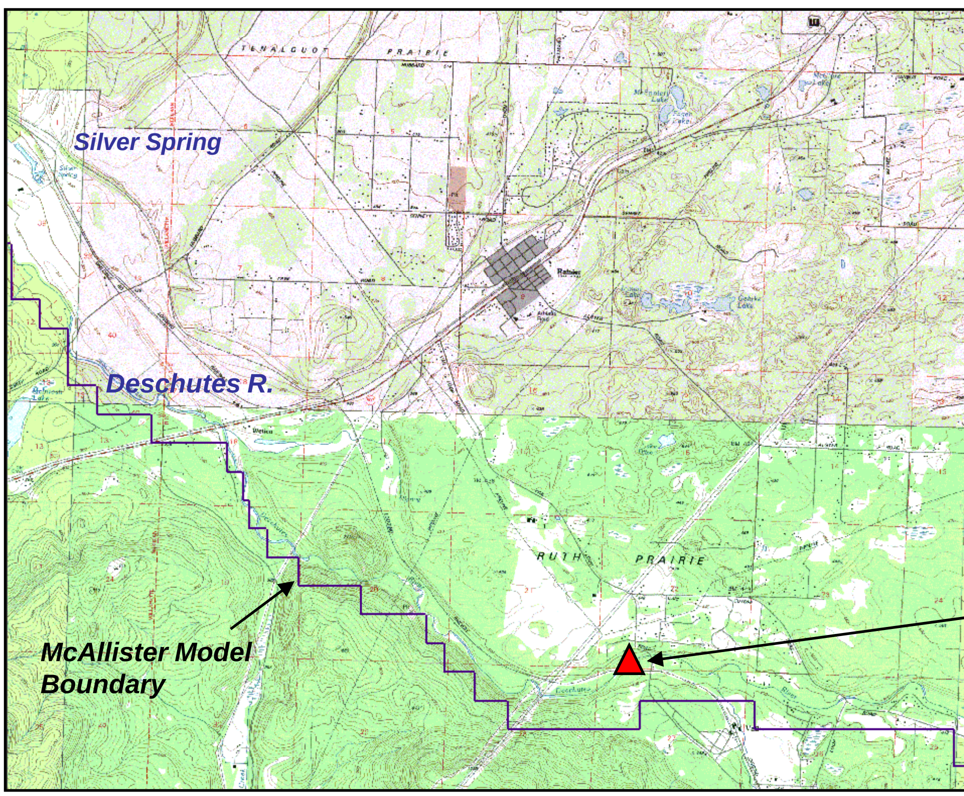
In the summer of 2003, Ecology conducted field studies along the Deschutes River to obtain an improved understanding of how groundwater affects stream temperatures and water quality conditions (Sinclair and Bilhimer, 2007). The study involved measuring flows on August 4, 2003 at the Rainier gage (30.7 cfs) and the E Street Bridge gage (79.1 cfs), which equate to a flow increase of 49.6 cfs. The estimated August 2003 contribution from tributary creeks and springs was 10.65 cfs, indicating a net increase from groundwater discharge of 38.95 cfs.

The August 2003 flow measurements were not the lowest of that year. According to the USGS station data, the low flow for the Rainier gage occurred in early September (19 cfs) and for the E Street Bridge during early October (51 cfs). No tributary inflow data were collected to correspond with the lowest flows (the September-October period). Consequently, a range similar to the measured value will be assumed. If the contribution from the tributaries was between 5 and 10 cfs during the low-flow period, the contribution from groundwater would have been between 22 and 27 cfs. Golder believes this is a reasonable estimate given the existing information.

Note: These estimated flows include groundwater contributions from both the western and eastern sides of the river. The McAllister model simulates flow only to the east of the Deschutes River. This assumption should be accounted for when comparing estimated and modeled flows.

E Street Bridge Gage (#12080010)





Rainier Gage (#12079000)

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City of Yelm – Future SW Yelm Wellfield Simulations

TITLE

Location of Stream Gage Stations along Deschutes River

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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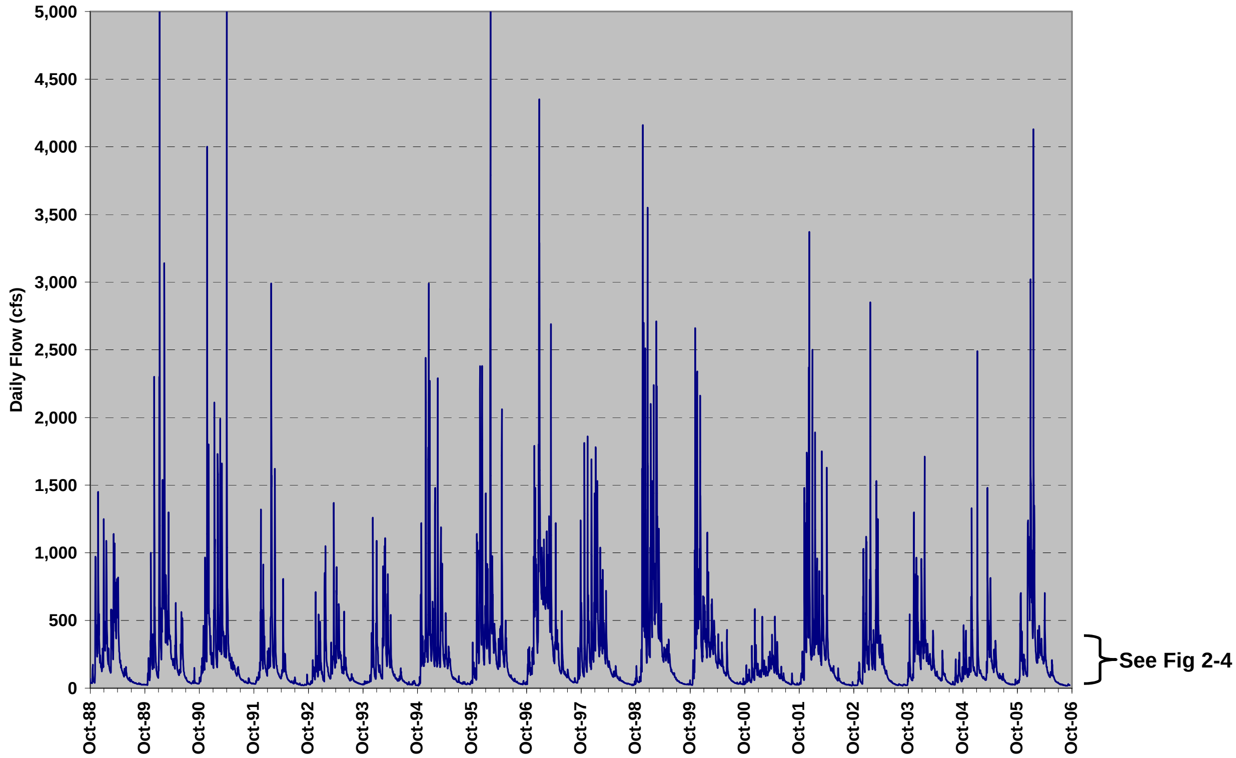

Golder Associates

TITLE

Recorded Daily Flows at USGS Gage near Rainier (#12079000) – 1988-2006

City of Yelm – Future SW Yelm Wellfield Simulations

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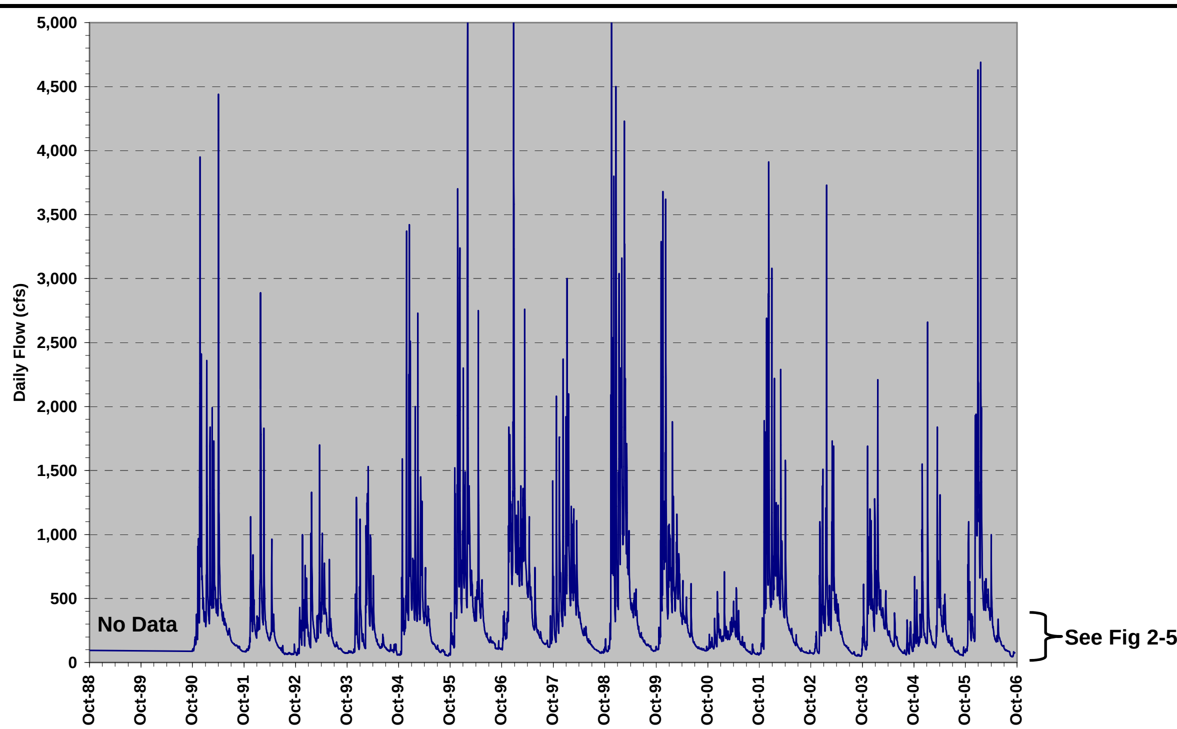

Golder Associates

TITLE

Recorded Daily Flows at USGS Gage at E Street Bridge, Tumwater (#12080010) – 1988-2006

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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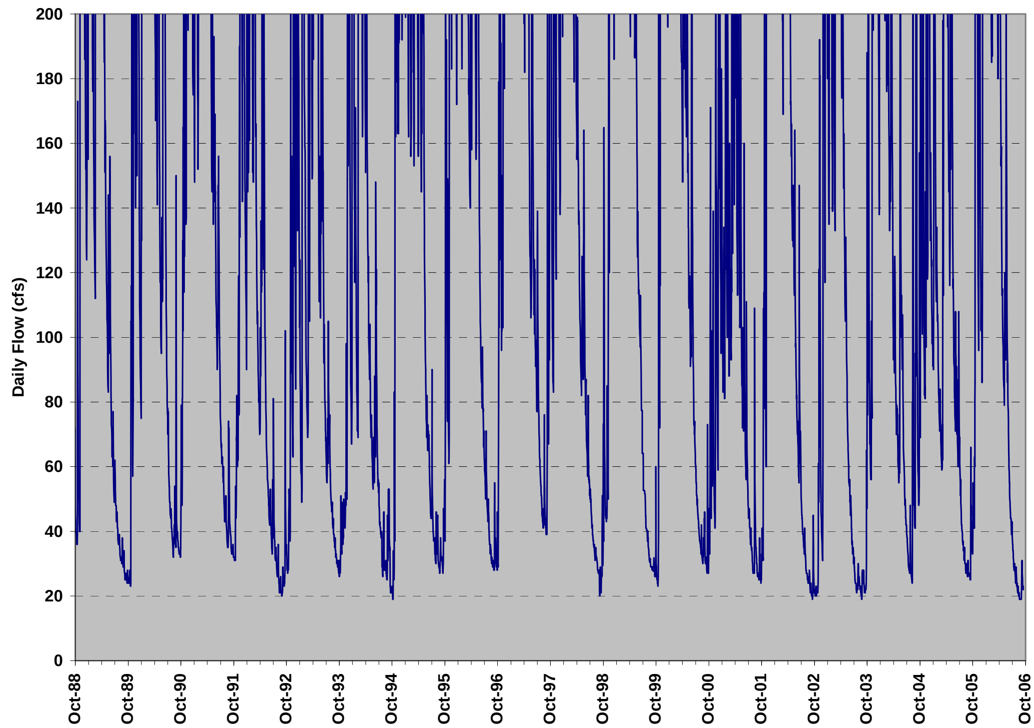
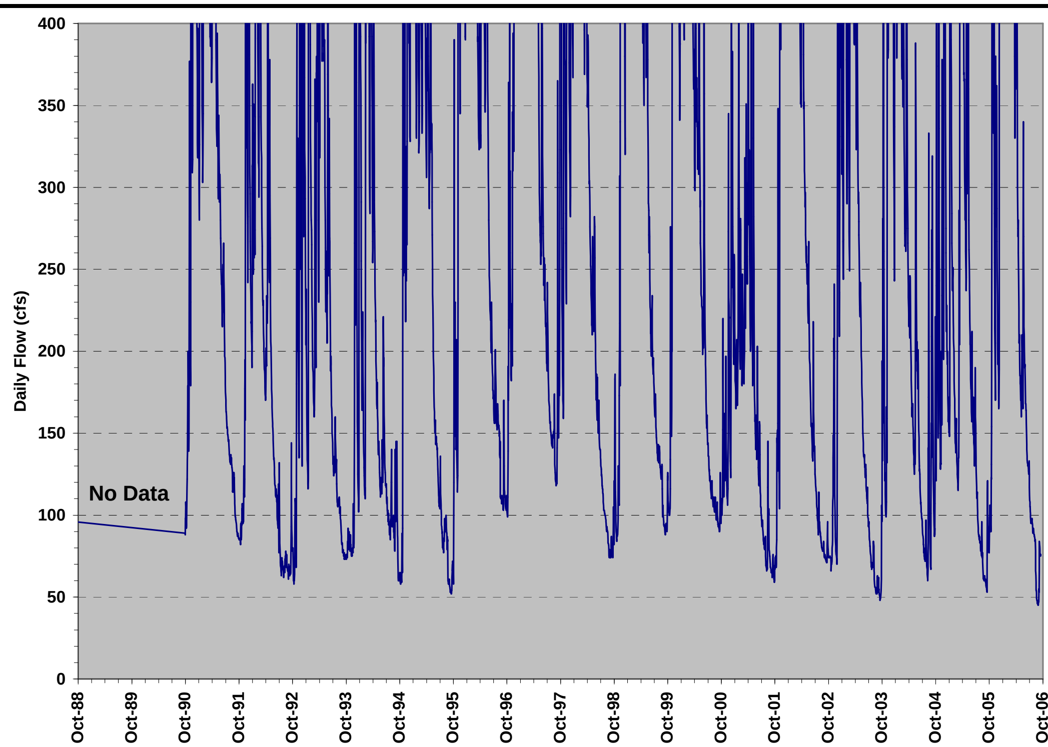


Golder Associates

TITLE
Recorded Daily Flows at USGS Gage near Rainier (#12079000) – 1988-2006 (Detail)

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500	
CHECKED PAB	SCALE	DWG No.	
REVIEWED JS	FILE No. Sims_figs_port.ppt	FIGURE No. 2-4	



Golder Associates

TITLE
Recorded Daily Flows at USGS Gage at E Street Bridge, Tumwater (#12080010) – 1988-2006 (Detail)

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500	
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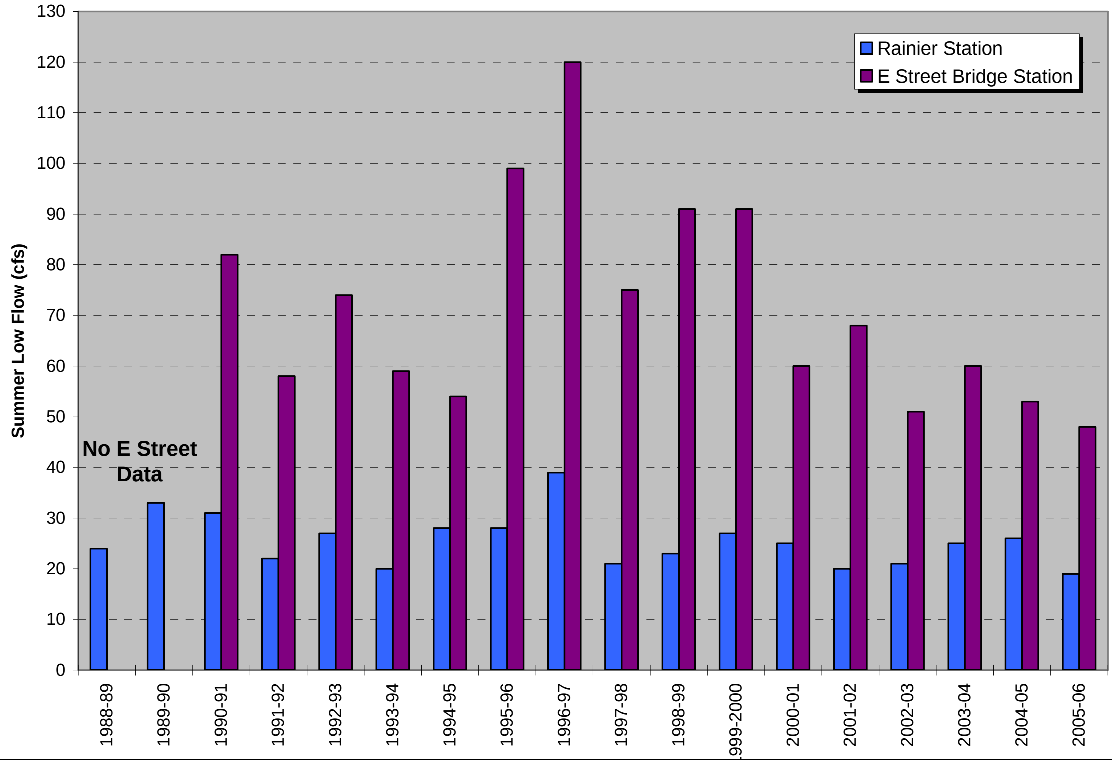
REVIEWED JS	FILE No. Sims_figs_port.ppt	FIGURE No. 2-5	



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TITLE **Annual Summer Low Flows - USGS Gages near Rainier and E Street Bridge, Tumwater (1988-89 to 2005/06)**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500	
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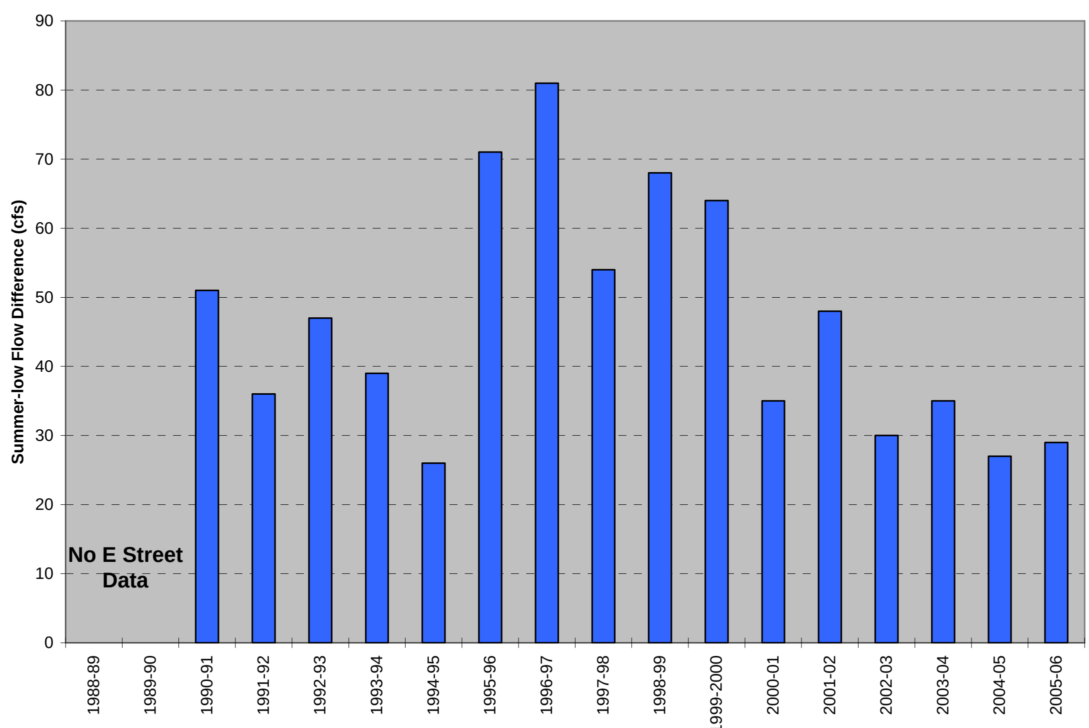
REVIEWED JS	FILE No. Sims_figs_port.ppt	FIGURE No. 2-6	



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TITLE **Difference between Summer Low Flows - USGS Gages near Rainier and E Street Bridge, Tumwater (1988/89 to 2005/06)**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500	
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3.0 MODEL CHANGES AND CALIBRATION UPDATES

This section summarizes the changes that were made to the model and the rationale and assumptions for these changes. This section also presents the results of these changes in the context of groundwater levels and discharge rates for the steady-state and transient calibration simulations.

3.1 Model Changes

3.1.1 Cell Cleanup

Golder reviewed the distribution of model cells along the lower reach of the Deschutes River and identified several model cells west of the river that were incorrectly active. These cells were converted to inactive status before progressing with changes to the head-dependent boundary conditions and model layering along the river (Section 3.2 and 3.3 below). These changes had a relatively minor effect on model results.

3.1.2 Activation of Vashon Sequence in the Middle Deschutes River Valley

This task involved activating numerous model cells along the middle reach that were made inactive during the model's original construction (CDM, 2002a). At that time, these cells were excluded because of the inability to obtain a stable model at steady-state using standard MODFLOW solvers. Although the solver was upgraded during construction to the more robust MODFLOW-SURFACT program (HydroGeoLogic, 1996), these cells were not converted to active.

The activation process included initially designating the area of cells to be converted and reviewing the layer surface elevations that had been previously assigned to them. In most cases, the original elevations required correction, and a significant resurfacing effort was necessary. Previously, the highest active cells in this area were in layer 8, and the layer top elevations had been assigned land elevations. These land elevations were reassigned to the highest newly-activated model layer 3 cells, and manual adjustments were made to all intervening cells surfaces between layers 3 and 8. Figures 3-1 and 3-2 show the previous and updated layer 3 (Vashon Advance Outwash [Qga] aquifer) active cell extents.

3.1.3 Middle Deschutes River Reach Boundary

This task involved assigning *Constant Head* boundary conditions to those newly-activated cells in model layer 3 along the reach of the Deschutes River that connects the existing upper and lower reaches (Note: *Constant Head* boundary conditions fix the groundwater level at specified cells and remain at this level regardless of changes in recharge and pumping. This allows water to move both into and out of the model across the boundary). Figures 3-1 and 3-2 show the distribution of boundary conditions and active model cells in layer 3 for the previous and updated versions of the model in the middle Deschutes area, respectively. The assigned constant head values were set to match the approximate level of the river and ranged from 202 to 290 feet mean sea level (msl). No changes were made to the boundary conditions in the previously-defined reaches.

The use of the *Constant Head* condition was a reasonable approximation to actual conditions for the Deschutes River. The exchange between the *Constant Head* cells representing the river and the aquifers is controlled by the hydraulic conductivity assigned to these cells and the adjacent cells laterally and below. Because the underlying cells have a relatively low conductivity, most of the modeled flow occurs from the laterally-adjacent cells. This is similar to actual conditions as the river bed probably consists of some low permeable silty material that limits exchange of water with the aquifer. This approach is also relatively conservative because the modeled hydraulic effects of future higher groundwater pumping by the municipalities would be more readily translated to the river than if an alternative boundary condition (such as the *River* or *Stream* package) were employed.

3.1.4 Silver Spring and Creek

The previous version of the model did not represent Silver Spring and the associated creek that drains into the Deschutes River at approximately RM 17.4 (Sinclair and Bilhimer, 2007). Figures 3-3 and 3-4 show the locations of the spring and creek; Figures 3-5 through 3-8 are photographs taken of the spring and creek in June 2007. Figure 3-2 shows the location of *Drain* cells that were added to the model to represent the spring and creek in layer 3. (Note: *Drain* cells allow water to exit the model to mimic groundwater discharge to springs and creeks).

No formal monitoring of groundwater discharge at Silver Spring and the creek has been conducted. However, the USGS reported a measured flow of 1.1 cfs in August 1988 (Drost et al., 1999) near where the creek joins the Deschutes River. In June 2007, the Squaxin Indian Tribe measured the flow in the creek increasing from 5.2 cfs at the outfall of the spring pond to 7.3 cfs at the mouth with the Deschutes River, indicating a net gain of 2.1 cfs. For the purpose of updating the steady-state calibration, a groundwater discharge target of between 1.0 and 2.0 cfs was set for the spring and creek (Konovsky, pers comm. 2007a). The assigned *Drain* condition elevations ranged from 278 to 280 feet msl. Some manual adjustments to the *Drain* conductance parameter were made to enable the group of model cells to collectively discharge groundwater at a rate within the target range. These results are presented in Section 4.0 of this report.

3.1.5 East Olympia Wellfield Pumping

The previous version of the steady-state model (which represents long-term annual average conditions) incorrectly simulated pumping at Olympia's Hoffman and Shana Park wells (Wells 3 and 11). Table 3-1 summarizes the previously-simulated pumping rates and assigned aquifers, and the recommended changes. Although the City of Olympia has recently obtained a water right to operate the third well in wellfield (the Indian Summer well, Well 20), this well has been inactive and the model therefore correctly simulates no pumping.

TABLE 3-1

Summary of Pumping Rates and Layer Assignments for the City of Olympia Wells

Well	Feature	Original Model	Updated Model
Hoffman (Well 3)	Pumping Rate	115 gpm	zero (1,2)
	Aquifer (model layer no.)	Lower TQu (9)	Upper TQu (8)
Shana Park (Well 11)	Pumping Rate	204 gpm	350 gpm(1)
	Aquifer (model layer no.)	Qgr (1)	Qga (3)

Notes: (1) – The original pumping rates are based on 1998-2002 monthly records, and are not the proposed future pumping rates. (2) – Although the Hoffman well has been pumped in the recent past as an emergency source, the average rate is less than 10 gpm and is therefore too low to warrant a nonzero rate.

3.1.6 Pre-Vashon Gravel (Qpg) Aquifer Transmissivity (Layers 5 and 6)

The previous version of the model simulated the transmissivity of the Qpg aquifer as 840 square feet per day (sq.ft/day) at the Indian Summer well. The simulated aquifer thickness is 14 feet and the hydraulic conductivity 60 feet per day (ft/day) (Figure 3-9). This transmissivity value is a factor of three lower than the estimated value obtained for the Indian Summer well from well testing (Golder, 2007b). As transmissivity has a significant effect on future drawdown at this well, the model transmissivity was increased to 2,800 sq.ft/day by expanding the areal extent of the 200 ft/day property zone further south (Figure 3-10).

3.1.7 Upper TQu Aquifer Transmissivity (Layer 8)

The previous version of the model simulated the TQu unit using two layers (8 and 9); the upper layer (layer 8) had a thickness of up to 150 feet, and the lower layer had a thickness varying from 10 to several hundred feet. The base of layer 9 represents the boundary between the unconsolidated sediments and the relatively impermeable bedrock. The model used a single horizontal hydraulic conductivity (Kh) value of 75 ft/day and a single vertical hydraulic conductivity (Kv) of 0.03 ft/day for both layers. The Kh value was based on the median value derived by the USGS as part of the development of the Northern Thurston County model (Drost et al., 1999). These values are shown on Figure 3-11. The high degree of anisotropy is representative of the undifferentiated, glacial and nonglacial, highly-stratified sands, gravels, silts and clays that have been described for this unit.

The transmissivity of the upper part of the TQu aquifer in the East Olympia Wellfield area (13,875 sq.ft/day) was noted to be a factor of four higher than the estimated value obtained from testing at the Hoffman well (Well 3) of 3,340 sq.ft/day (Golder, 2007b). The layer thickness at this well was 150 feet. Therefore, the model was revised in the northwest part by raising the base of layer 8 by 100 feet to produce a layer thickness of 50 feet, and maintaining the assigned hydraulic conductivity values. Figure 3-12 shows the area in which this change was made. This resulted in a transmissivity for model layer 8 in this area of 3,750 sq.ft/day. Figures 3-13 and 3-14 show the original and revised layering along a west-east section through the wellfield area, respectively.

By maintaining the total thickness and hydraulic conductivity in the two TQu layers at 75 ft/day, the overall TQu transmissivity (the sum of layers 8 and 9) remained unchanged from the previous model version. Because of the relatively high anisotropy for these two layers, a well pumping from layer 8 in the revised area would continue to draw almost all of its water from layer 8 despite the decreased layer 8 transmissivity and increased layer 9 transmissivity.

3.1.8 McMonigle Pumping

The original version of the model represented pumping for a setoff water rights listed under the ownership of McMonigle at a parcel of land located about 2 miles south of downtown Yelm, alongside Yelm Creek. This pumping was as follows:

- Well 1 – 300 acre feet per year (afy), irrigation, all from the Qga (outwash) aquifer, and
- Well 2 – 18.8 afy, domestic/stock, all from the Qga aquifer.

New information was obtained for these water rights, summarized in a technical memorandum prepared for the property owners (PGG, 2007). Table 3-2 presents the current understanding of the wells. Three active wells exist (one 6-inch, one 10inch and one 12-inch). The screened interval of the 10-inch-diameter well draws water from the Vashon Advance Outwash (Qga), the Pre-Vashon Gravel (Qpg), and the upper part of the deeper, Undifferentiated Tertiary (TQu) aquifer. Table 3-3 presents the updated modeled distribution of pumping for these three wells.

TABLE 3-2

McMonigle Well Construction and Pumping

Well ID (nominal diameter)	Depth (ft)	Diameter (inches)	Perforations (ft interval)	Depth to Water (ft)	Water Use	Seasonal Pumping
6-inch well “	0 - 52 52 -105	6 6	Open hole 47-52	16 90	Domestic, stock	All-year
10-inch well	0 - 119 119 - 358	10 8 8 8 8	100 to 116 163 to 178 261 to 266 296 to 298 312 to 358	? 32	Irrigation	April to September Only
12-inch well	0 - 81 81 - 146	12 ?	64 to 80 ?	12 5	Domestic	All-year

TABLE 3-3

McMonigle Well Distribution of Pumping By Aquifer/Model Layer

Well ID (nominal diameter)	Perforations (ft interval)	Aquifer	Model Layer	Total Pumping (afy)	Percentage for each layer	Peak annual rate (gpm)
6-inch well	Open hole 47-52	Qga	3	18.8	100	11.7
10-inch well	100 to 116	Qga	3	294.19	39	135
	163 to 178	Qpg	5,6		10	36.5
	261 to 266 296 to 298 312 to 358	TQu(u)	8		59	193
12-inch well	64 to 80	Qga	3	5.81	100	3.6

The pumping at the 10-inch-diameter well is distributed by weighting the assigned conductivities and screened interval of each layer.

3.1.9 Water Budget Boundary Condition Definitions

Table 3-4 presents the updated list of boundary conditions for which the model calculates discharge rates. The previous model used two boundary reaches (nos. 14 and 23) to represent the Deschutes River. Following the revision to the Deschutes River in the model (see Sections 3.1.3 and 3.1.4 of this report), the middle section was assigned zone number 4 and Silver Spring/Creek number 35. No other changes were made to the previous zone system.

TABLE 3-4

Previous and Updated Model Boundary Reach Zonation

Zone No.	Previous Version	Updated Version	Comments
1	U. McAllister Valley Springs	U. McAllister Valley Springs	Tributary to McAllister Creek. Excludes McAllister Spring
2	Lake St. Clair	Lake St. Clair	
3	McAllister Creek	McAllister Creek	
4	Not used	M. Deschutes River	Between Macintosh and Offutt Lakes
5	McAllister Valley bluff springs	McAllister Valley bluff springs	Tributary to McAllister Creek
6	L. Nisqually River – RM 4.3 to Puget Sound	L. Nisqually River – RM 4.3 to Puget Sound	Reach below minimum in stream flow point.
7	Up-gradient boundary	Up-gradient boundary	
8	Budd Inlet	Budd Inlet	
9	M. Nisqually R. – from zone 22 to zone 33 (new U. Nisqually)	M. Nisqually R. – from zone 22 to zone 33 (new U. Nisqually)	
10	Eaton Creek	Eaton Creek	Tributary to Lake St. Clair
11	Spurgeon Creek	Spurgeon Creek	Tributary to Deschutes R.
12	Puget Sound	Puget Sound	
14	L. Deschutes River	L. Deschutes River	Downstream from new M. Deschutes reach
15	McAllister Spring	McAllister Spring	Tributary to McAllister Creek
16	Hicks Lake	Hicks Lake	Tributary to Woodland Creek
17	Long Lake	Long Lake	
18	Pattison Lake	Pattison Lake	
19	Long-Pattison wetland area	Long-Pattison wetland area	
20	First 5,000-ft of Nisqually above RM 4.3	First 5,000-ft of Nisqually above RM 4.3	
21	Second 5,000-ft of Nisqually above RM 4.3	Second 5,000-ft of Nisqually above RM4.3	
22	Third 5,000-ft of Nisqually above RM 4.3	Third 5,000-ft of Nisqually above RM 4.3	
23	U. Deschutes River	U. Deschutes River	Upstream from new M. Deschutes reach
24	Hicks-Pattison wetland area	Hicks-Pattison wetland area	Tributary to Woodland Creek
25	Woodard Creek	Woodard Creek	
26	Woodland Creek	Woodland Creek	Starts at the outlet from Long Lake
31	Kalama Creek Springs	Kalama Creek Springs	Tributary to Nisqually R.
32,34	Yelm Creek	Yelm Creek	Tributary to Nisqually R.
33	U. Nisqually River	U. Nisqually River	Upstream from Thompson Creek inflow. Previously included in Zone 9
35	Not used	Silver Spring and Creek	Tributary to Deschutes R.

3.2 Updated Steady-state Calibration

Golder reran the steady-state calibration after the model changes were completed. The steady-state calibration condition represents a long-term, average annual condition. The primary input flux is precipitation-derived recharge, which was not changed from the previous model version. The key calibration targets were also unchanged, and included 289 observation water levels (distributed across the four main aquifer units) and groundwater discharge rates at a series of key hydrologic features such as springs, rivers and lakes.

3.2.1 Groundwater Levels

Figures 3-15 through 3-20 illustrate (in plan view) a comparison of the modeled potentiometric levels for the previous and updated versions of the model for the Qga (layer 3), Qpg (layer 5) and TQu (layer 8) aquifer, respectively. A description of changes to the model results is provided below.

- Qga Aquifer (Figures 3-15 and 3-16). The modeled water levels in the Qga aquifer near the upper Deschutes River reach are several feet lower than those generated using the previous version. As expected, these figures also show the flow converging at the newly added Silver Spring and through the newly-activated Qga unit between the middle reach of the river and the remaining inactive area. The updated version of the model produces groundwater levels that are slightly lower near the lower reach of the Deschutes River.
- Qpg Aquifer (Figures 3-17 and 3-18). The modeled water levels in the Qpg aquifer near the upper reach of the Deschutes River are similar to those generated using the previous version. The modeled water levels near the lower reach of the Deschutes River are slightly lower (by up to 3 feet) than in the previous version.
- TQu Aquifer (Figures 3-19 and 3-20). The modeled water levels in the TQu aquifer along the upper reach of the Deschutes River are up to 5 feet higher than those generated using the previous version. Also, the irregular groundwater flow pattern that was previously generated in the area where the TQu outcrops at land surface is smoothed in the updated version. The updated version of the model produces water levels that are up to 2 feet lower near the lower reach of the Deschutes River.

Table 3-5 compares how closely the predicted groundwater levels match observed data sets for both the updated and previous version of the model. The results indicate that the changes have not significantly altered the calibration results on a layer-by-layer basis. The average residuals were improved slightly in the Qgr and Qga units, but worsened slightly in the Qpg and TQu units.

TABLE 3-5

Statistical Results for Original and Updated Models – All Target Wells

Model Layer(s)	Representative Aquifer	No. Target Wells	Previous Model[1]		Updated Model	
			Residual Mean (ft)	*Standard Deviation*	*Residual Mean (ft)*	*Standard Deviation*
1	Qgr	21	-10.9	15.1	-10.4	14.8
3	Qga	125	-9.0	28.4	-8.4	28.4
4-6	Qpg	108	5.7	27.4	6.4	26.2
7-9	TQu	35	21.1	38.7	22.4	40.8

Notes: (1) – this version was prepared for the City of Yelm (Golder, 2007a). Qgr – Vashon Recessional Outwash; Qga – Vashon Advance Outwash; Qpg – Pre-Vashon Gravel; TQu – Uundifferentiated Tertiary unit.

3.2.2 Water Budget and Flow Rates

Table 3-6 presents the overall water budget for the updated model compared to the previous version. The results indicate that the overall budget total for the updated model is 7 cfs lower than in the previous version, which equates to a 1.4 percent decrease in the total volume recharged and discharged. As expected from the nature of the model revisions, the largest change occurs to the *Constant Head* boundaries; both total inflows and outflows are reduced by equal amounts (6 cfs).

TABLE 3-6

Steady-state Model Water Budget by Boundary Condition Type (Entire Model)

Boundary Type	Previous Model		Updated Model		Notes
	IN	***OUT***	***IN***	***OUT***	
Constant heads	154	322	148	316	Includes SE boundary, Puget Sd., Budd Inlet, and Nisqually and Deschutes rivers
Recharge	343	0	343	0	Averages 23 inches/year. Includes 3,200 afy for Lake St. Clair seepage.
Pumping	0	26	0	26	
Rivers	5	33	6	32	
Drains	0	123	0	123	Includes all springs and side-valley seeps. Includes revised U. Nisqually River and Kalama Creek Springs.
Totals	**504**	**504**	**497**	**497**	

Note: All rates are in cfs.

Table 3-7 presents the water budget for specific hydrologic features of interest in the model area. No significant changes occur to the discharge in the upper McAllister Valley, Nisqually River or Yelm area hydrology. Noticeable changes in discharge occur at individual reaches of the Deschutes River; the flow to the upper reach decreased by 4.7 cfs (to compensate for the addition of the Silver Spring and middle reach), whereas the flow to the lower reach increased by 3.6 cfs (due to activation of layers 3 through 7). The discharges to Spurgeon and Eaton creeks also decreased by 0.7 and 0.2 cfs, respectively.

TABLE 3-7

Current and Updated Steady-state Model Fluxes at Key Hydrologic Features

Hydrologic Feature	Original Model		Updated Model		Notes
	cfs	*afy*	*cfs*	*afy*	
McAllister Valley					
McAllister Springs	28.6	20,700	28.0	20,300	*Drain* cells at elev. 6.5 ft msl
Other upper valley spring/seeps	38.7	28,000	38.0	27,500	*Drain* cells. Inc. Abbott Sp.
McAllister Creek	1.9	1,400	1.9	1,400	*River* cells in layer 4
Valley-bluff springs	2.9	2,100	2.8	2,050	*Drain* cells in layers 1 and 3.
Lakes/Wetlands					
Lake St. Clair	-1.0	-725	-1.0	-725	*River* cells
Hicks Lake	0.1	80	0.02	12	*River* cells in layer 2
Long Lake	1.7	1,200	1.5	1,080	*River* cells in layer 2
Pattison Lake	2.1	1,500	2.1	1,500	*River* cells in layer 2
Tri-lake wetland areas	1.9	1,400	1.6	1,100	*River* cells in layer 2
Upland Creeks					
Eaton Creek	4.1	2,900	3.9	2,840	*River* cells in layer 1
Spurgeon Creek	6.7	4,900	6.0	4,040	*River* cells in layer 1
Woodland Creek	6.0	4,300	5.9	4,300	*River* cells in layers 1 & 2
Nisqually River					
Lower reach (below RM 4.3)	31.7	22,900	31.3	22,600	*Constant head* and *Drain* cells
15,000-ft reach upstream from RM 4.3	26.7	19,300	26.4	19,100	
Middle reach	14.5	10,600	14.4	10,400	
Upper reach	23.4	16,900	23.4	16,900	
Deschutes River					
Lower reach	10.2	7,400	13.8	10,000	*Constant head* cells
Middle reach	NA	NA	2.3	1,600	
Upper reach	22.3	16,100	17.6	12,700	*Constant head* and *Drain* cells
Other Hydrologic Features					
Silver Spring	NA	NA	2.0	1,400	*Drain* cells in layer 3
Yelm Creek	0.9	670	0.9	670	*River* cells in layer 1
Kalama Creek Springs	4.4	3,200	4.4	3,200	*Drain* cells in layer 5

Note: (-) = net flow into the model. The definition of the Nisqually River into individual reaches is that employed by HDR/SSPA (2006). NA – not assessed.

3.3 Updated Transient Calibration

The transient calibration includes simulating the period from October 1989 to September 2005 using a combination of annual stress periods (from 1989 to 2001) and monthly stress periods (from October 2001 to September 2005). This was the same time period that groundwater pumping and recharge rates were simulated using the updated model.

3.3.1 Groundwater Levels

Figures 3-21 through 3-26 show the simulated groundwater levels during the 13-year calibration period for six key wells. For comparison, these plots also show the water levels that were generated by the previous model version for the transient calibration performed for the City of Yelm (Golder, 2007a). Overall, the model changes have minimal effect (less than 0.2 foot change) on these water levels. However, the water levels in Well TW-3 (completed in the Qpg aquifer) show a higher change compared to the previous model. Although none of the model changes were made in the immediate area of this well, it is likely that this change is mostly due to the increase in Qpg aquifer conductivity near the Indian Summer well (Figure 3-10).

3.3.2 Water Budget and Flow Rates

Figures 3-27 through 3-36 show the simulated groundwater flow rates at several key hydrologic features during the transient calibration period. These plots also show the discharge rates that were generated for the previous model version of the transient calibration (Golder, 2007a). Two additional discharge features – the middle Deschutes River (Figure 3-34) and Silver Spring/Creek (Figure 3-35) – have been added to the existing set and therefore have no previous discharge rates to compare. The model changes have resulted in relatively small changes in discharge rates for these features. Overall, the discharge rates are slightly lower than for the previous model version, which is consistent with the slightly lower model heads (Section 4.2.1 of this report).

3.4 Discussion of Revised Deschutes River Representation

3.4.1 Overview

Figure 3-36 shows the model-simulated discharge to the entire Deschutes River within the model domain from October 2001 to September 2005 for the previous and updated model versions. These results consist of the sum of the groundwater discharge to (1) Spurgeon Creek (which enters the Deschutes River at approximately RM 9.3), (2) Silver Creek and (3) the three defined river reaches (upper, middle and lower) of the river. The results indicate that although the updated total monthly discharge is lower than previously simulated, the differences between the two are relatively small (generally less than 10 cfs, or less than 10 percent of the total previous flow). Although the highest differences occur in winter months, the summertime (low-flow period) discharge differences between the two models are consistently less than 0.5 cfs. Therefore, the total monthly discharge to the Deschutes River in the updated model has not changed significantly from previous model simulations, especially during the low-flow summertime.

As discussed in Section 2.0 of this report, the USGS estimated that the flow in the Deschutes River in August 1988 increased between Rainier and Tumwater by 54 cfs (Drost et al., 1999). After deducting inflows from the various tributaries to the river along this 25.3 mile reach, the net flow increase was 43.5 cfs. In August 2003, Ecology estimated that the flow in the Deschutes River between the same gages increased by 49.6 cfs (Sinclair and Bilhimer, 2007). After deducting inflows from the various tributaries to the river, the net flow increase was 38.95 cfs.

In reality, summertime flow to this reach of the river occurs because of the contribution from tributaries and groundwater discharging to the river from the eastern and western sides. Because the McAllister model only simulates groundwater flow from the eastern side, the model does not fully represent the total discharge to the river from groundwater. Assuming that the model simulates half of the total groundwater discharging to the river, the representative equivalent summer flows for the two studies would be as follows:

- USGS study in August 1988 = 24.8 cfs
- Ecology study in August 2003 = 19.5 cfs

3.4.2 USGS Study Discharge Rate

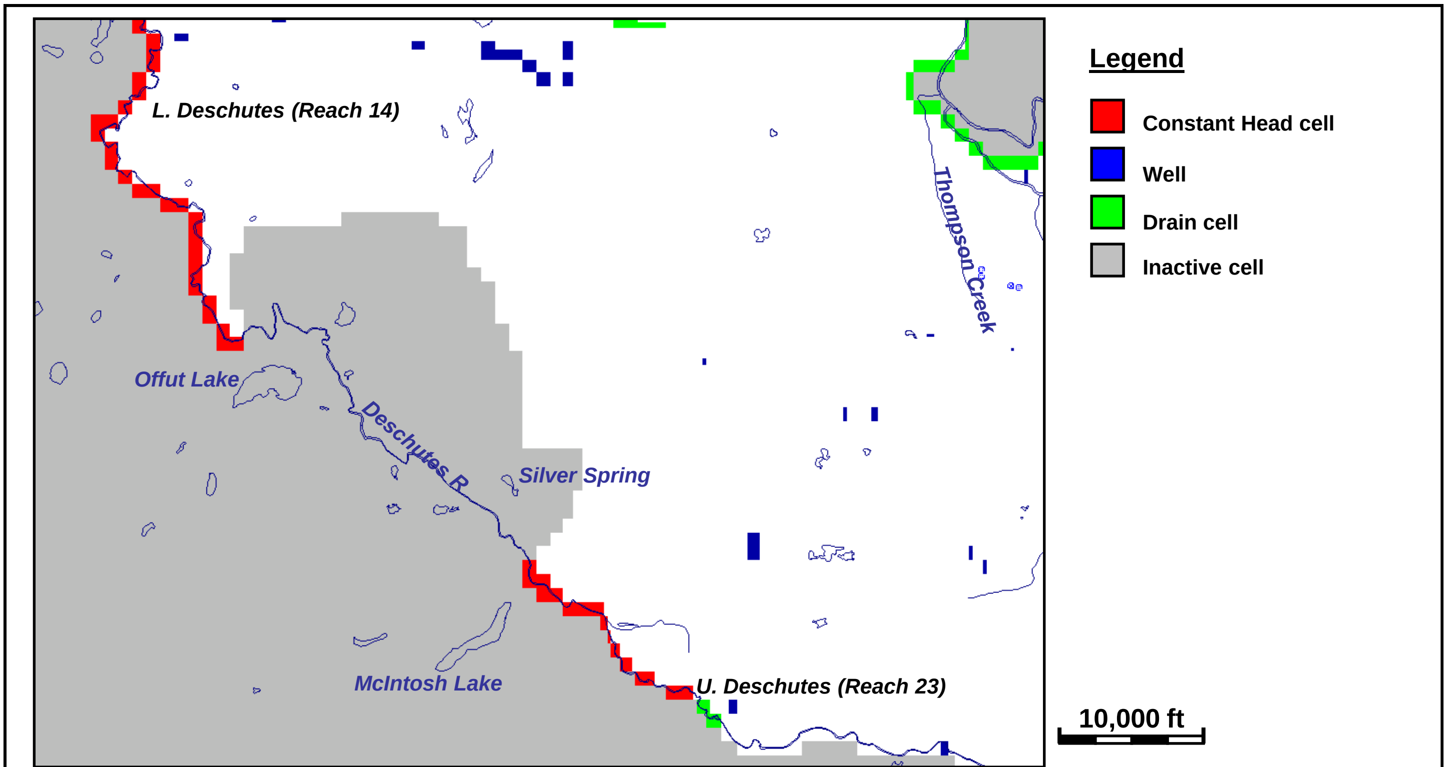
The model's steady-state calibration was for average 1988 conditions. Consequently, the modeled discharge the Deschutes River (41.7 cfs; Table 3-7) represents the average annual total discharge and is higher than the estimated August rate of 24.8 cfs. This is to be expected, as groundwater discharge would be expected to increase during times of the year when local aquifer heads are higher.

The model calibration simulated monthly discharge rates between October 2002 and September 2005. The simulated August discharge totals for the Deschutes River during this period were between 17.1 and 27.4 cfs, which are similar to the USGS rate for August 1988 of 24.8 cfs.

No field study has been conducted to estimate the likely average annual discharge to the river, which makes it very difficult to directly validate the model.

3.4.3 Ecology Study Discharge Rate

The time-varying calibration groundwater discharge rate increase between the two gages for August 2003 was 16.2 cfs (Figure 3-36), which is 3.2 cfs lower than the estimated rate for the eastern inflow of 19.5 cfs made using the Ecology study. The model does not simulate inflow that occurs from Chambers Creek to the Deschutes River, which was measured by Ecology as 1.15 cfs. If this flow is accounted for, the difference between the modeled and field estimate is 2.05 cfs. Golder considers this result to be good taking into account uncertainty regarding the estimated actual discharge rates and accounting for the tributary contributions.



Golder Associates

TITLE
Previous Model – Active Cells and Boundary Conditions (Layer 3)

City of Yelm – Future SW Yelm Wellfield Simulations

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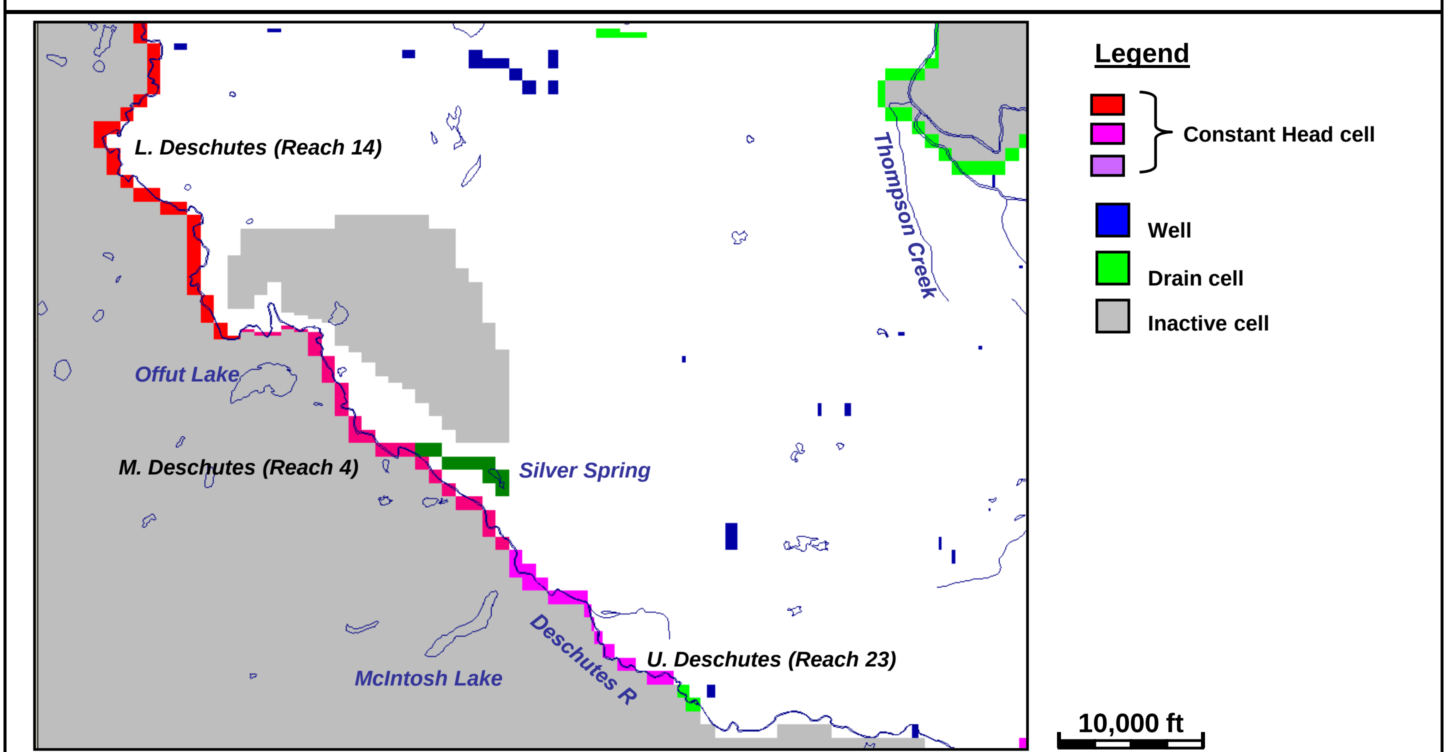

Golder Associates

TITLE
Updated Model – Active Cells and Boundary Conditions (Layer 3)

City of Yelm – Future SW Yelm Wellfield Simulations

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Golder Associates

TITLE **Location of Silver Spring/Creek**

City of Yelm – Future SW Yelm Wellfield Simulations

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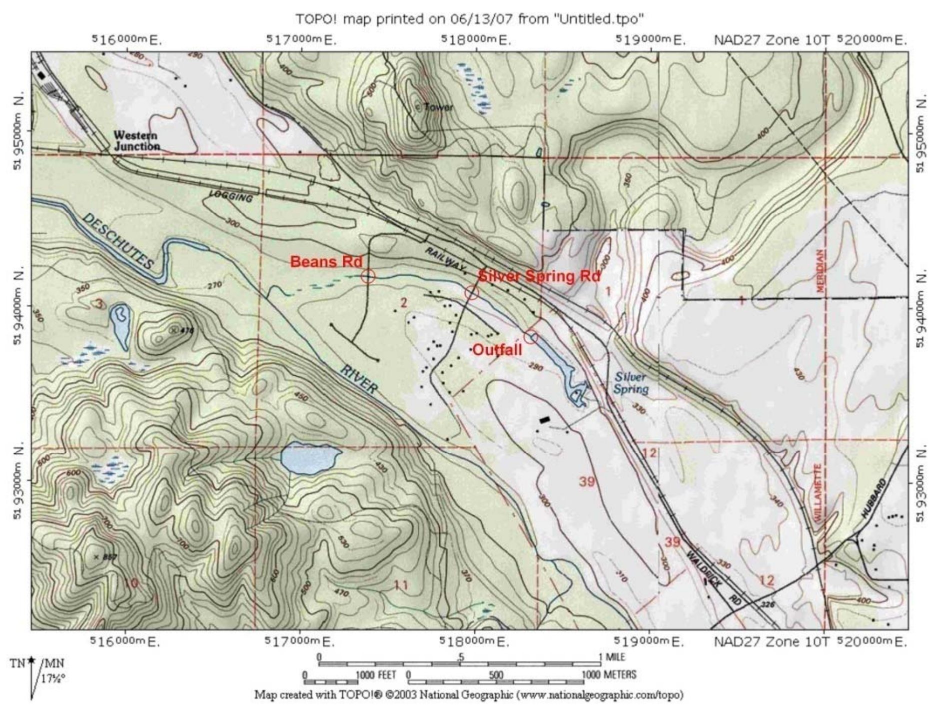

Golder Associates

TITLE **USGS Topography Map of Silver Spring/Creek Area**

City of Yelm – Future SW Yelm Wellfield Simulations

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CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.		FIGURE No.	3-4

TITLE

Silver Spring Outflow Berm Area

Golder Associates

City of Yelm – Future SW Yelm Wellfield Simulations

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CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.		FIGURE No.	3-5

TITLE

Silver Spring Creek at Silver Spring Road -1

Golder Associates

City of Yelm – Future SW Yelm Wellfield Simulations

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CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.		FIGURE No.	3-6

Golder Associates

TITLE

Silver Spring Creek at Silver Spring Road - 2

City of Yelm – Future SW Yelm Wellfield Simulations

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REVIEWED	JS	FILE No.		FIGURE No.	3-7

Golder Associates

TITLE

Flow in Silver Spring Creek at Bean Lane

City of Yelm – Future SW Yelm Wellfield Simulations

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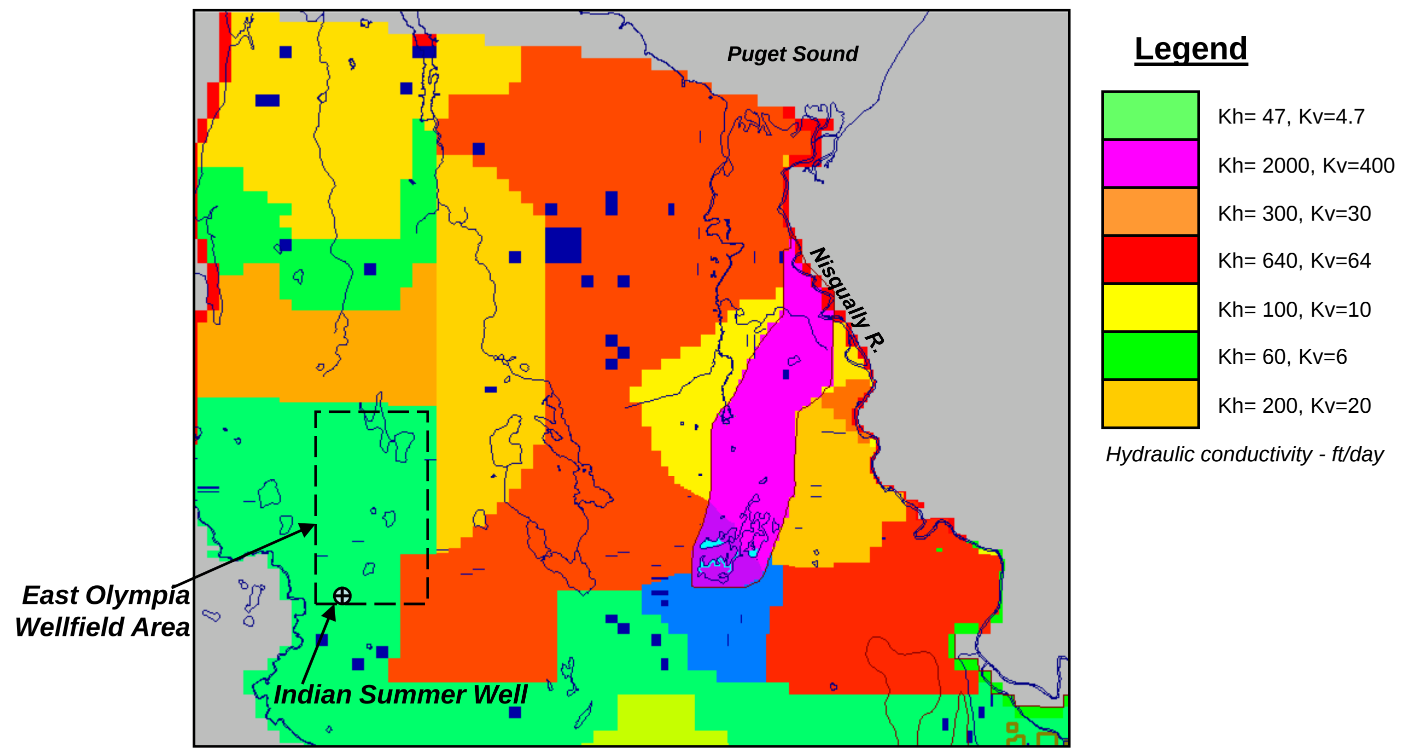

Golder Associates

TITLE
Previous Model – Layer 5 (Pre-Vashon Gravel Aquifer) Conductivity Zonation

City of Yelm – Future SW Yelm Wellfield Simulations

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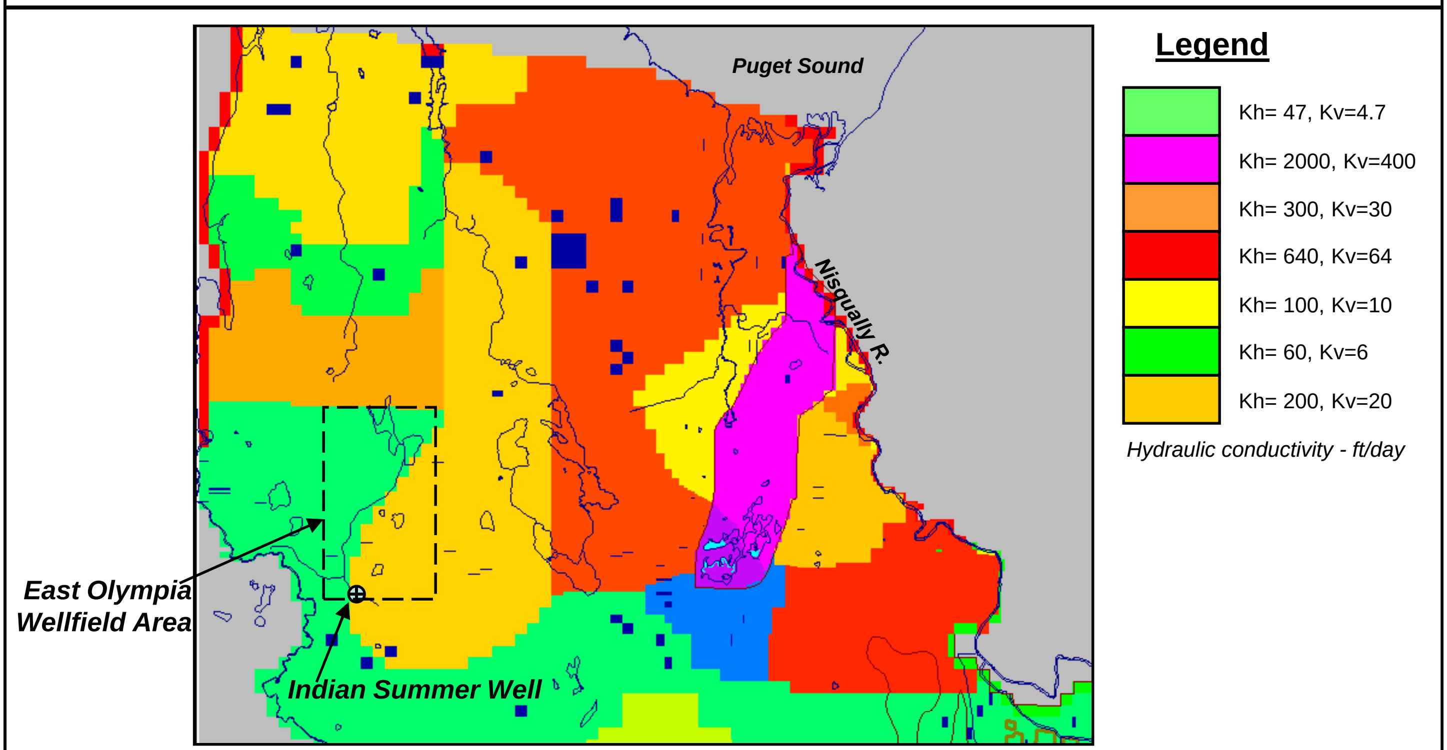

Golder Associates

TITLE
Updated Model – Layer 5 (Pre-Vashon Gravel Aquifer) Conductivity Zonation

City of Yelm – Future SW Yelm Wellfield Simulations

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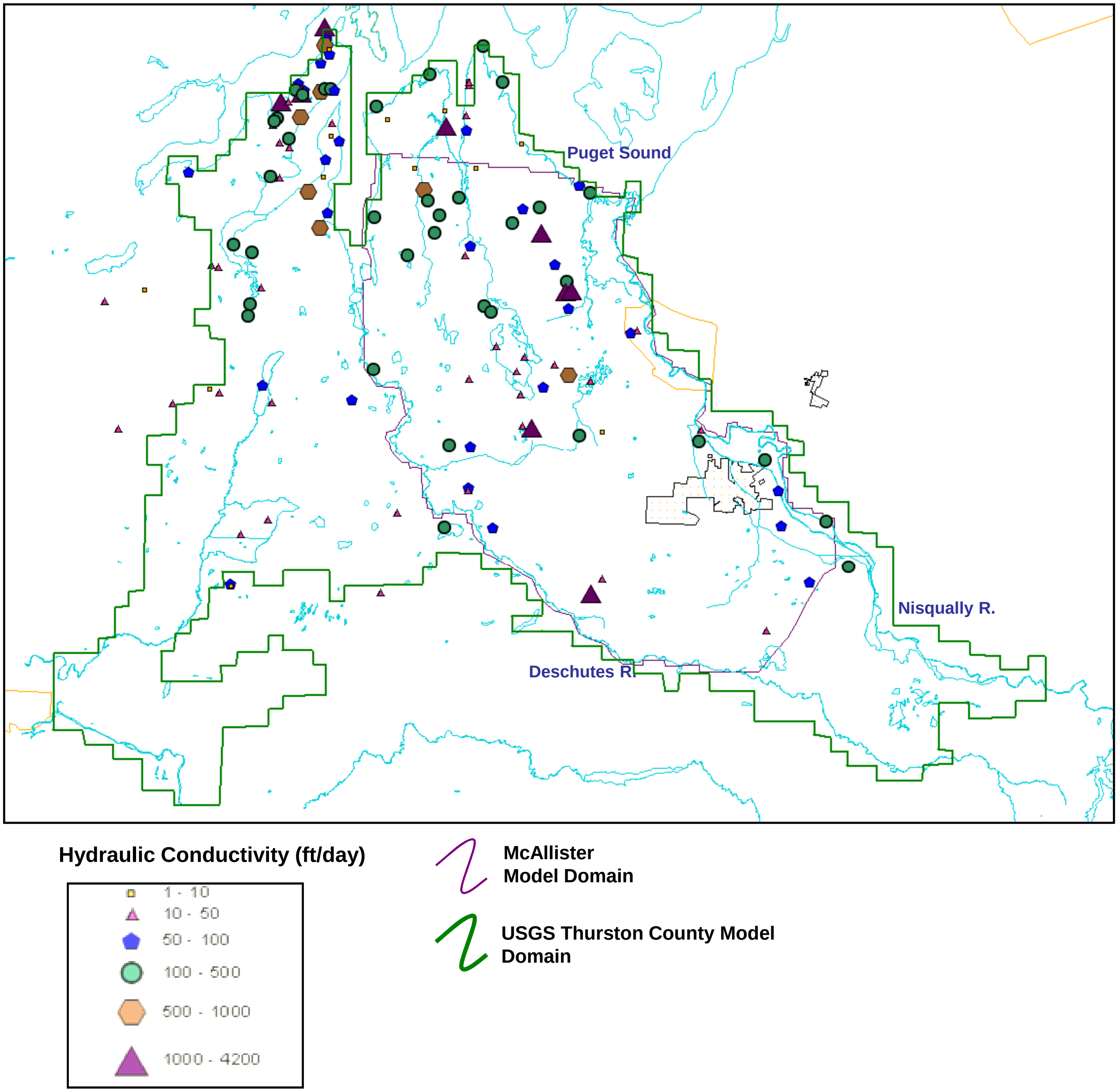

Golder Associates

TITLE

Hydraulic Conductivity Estimates for Wells Completed in the TQu Aquifer

City of Yelm – Future SW Yelm Wellfield Simulations

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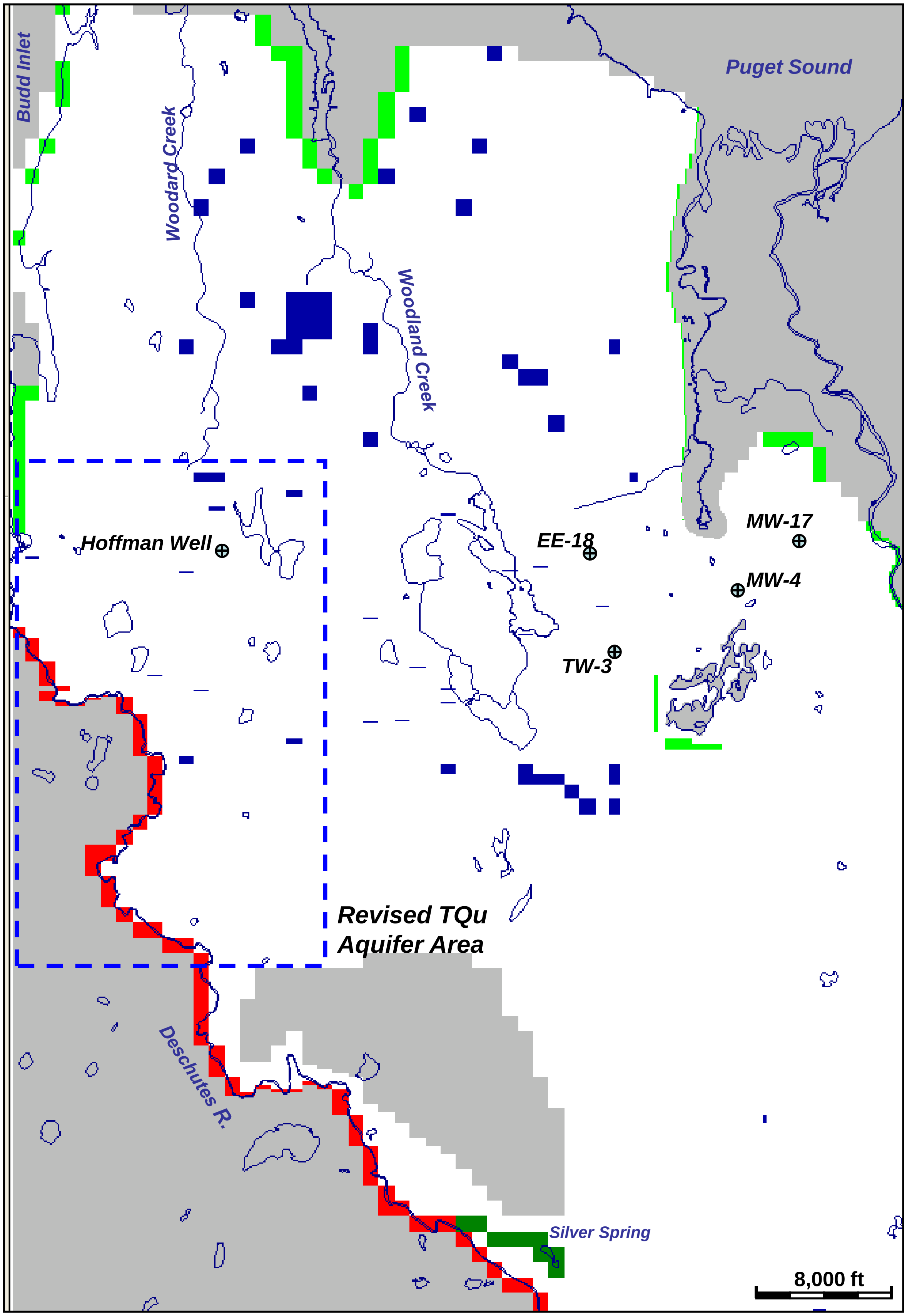

Golder Associates

City of Yelm – Future SW Yelm Wellfield Simulations

TITLE

Extent of Revised TQu Transmissivity Area (shown on the revised layer 3 plan view)

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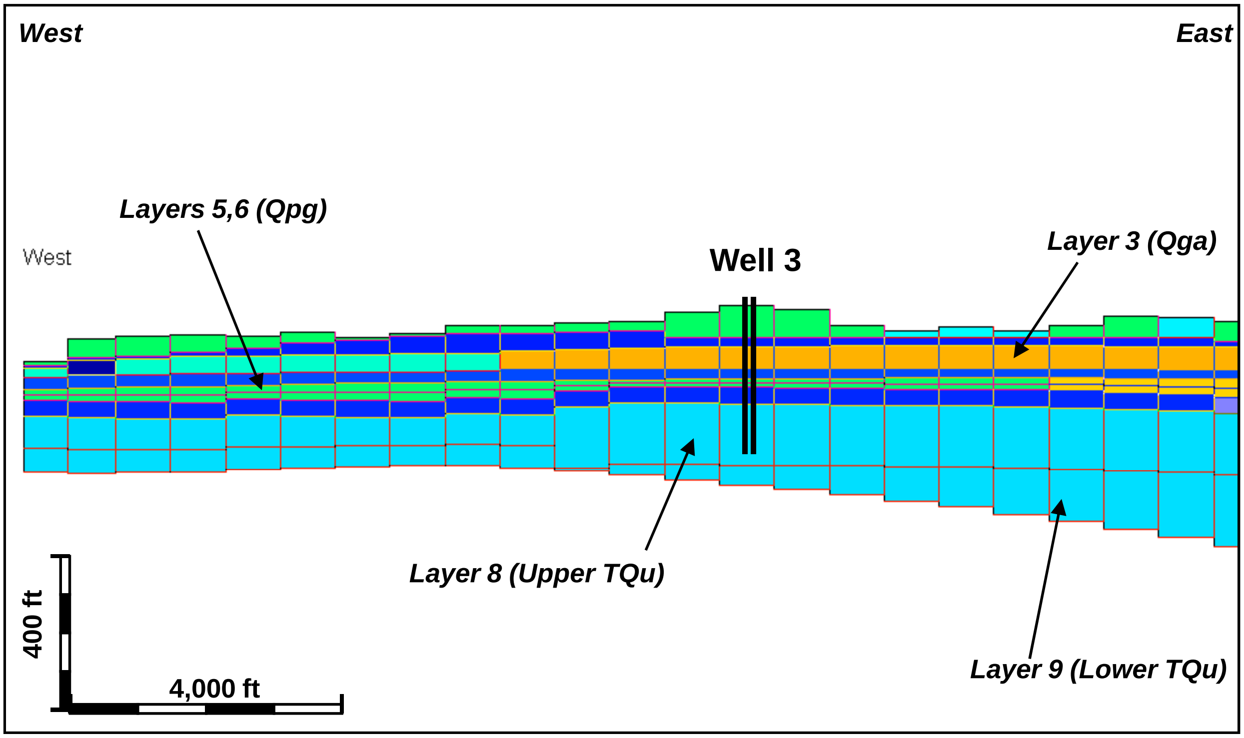

Golder Associates	TITLE Previous Model – Layer 8 (Upper TQu) in East Olympia Wellfield Area		
City of Yelm – Future SW Yelm Wellfield Simulations	DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
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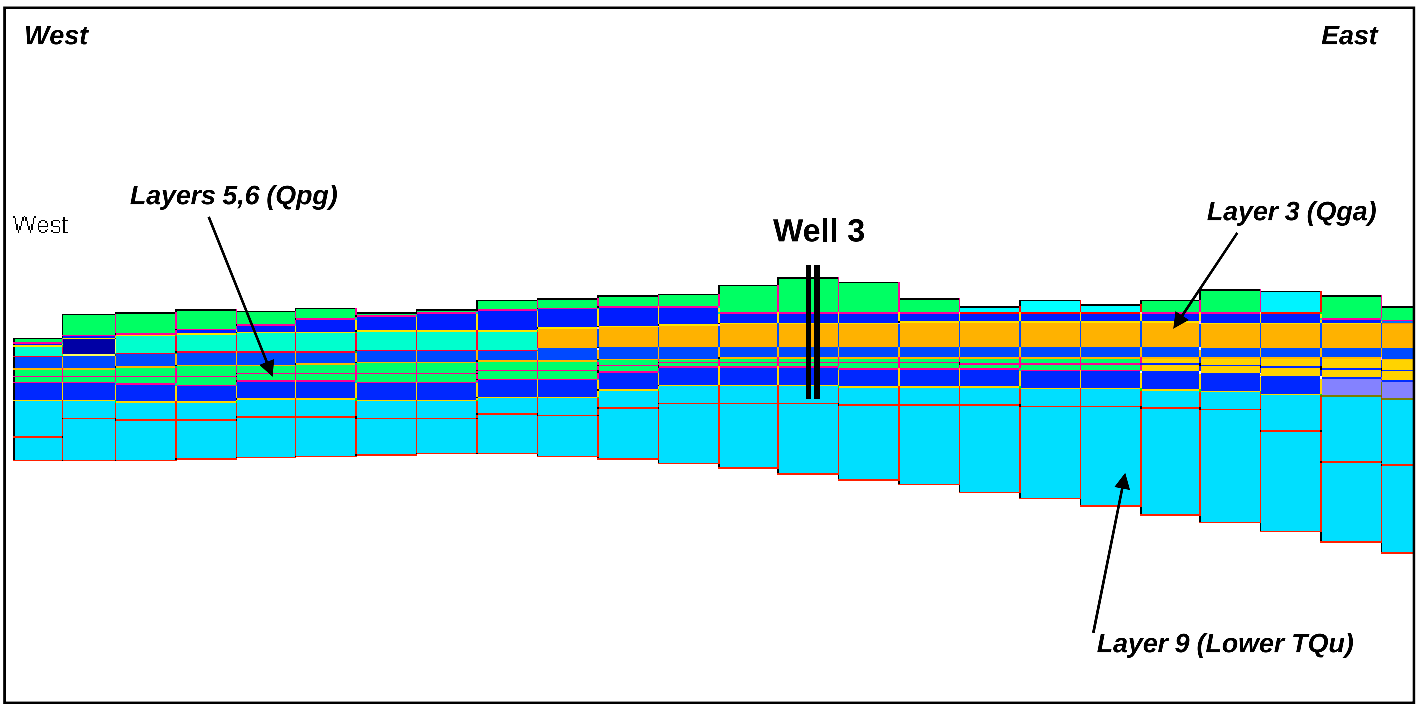

Golder Associates	TITLE Updated Model – Layer 8 (Upper TQu) in East Olympia Wellfield Area		
City of Yelm – Future SW Yelm Wellfield Simulations	DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
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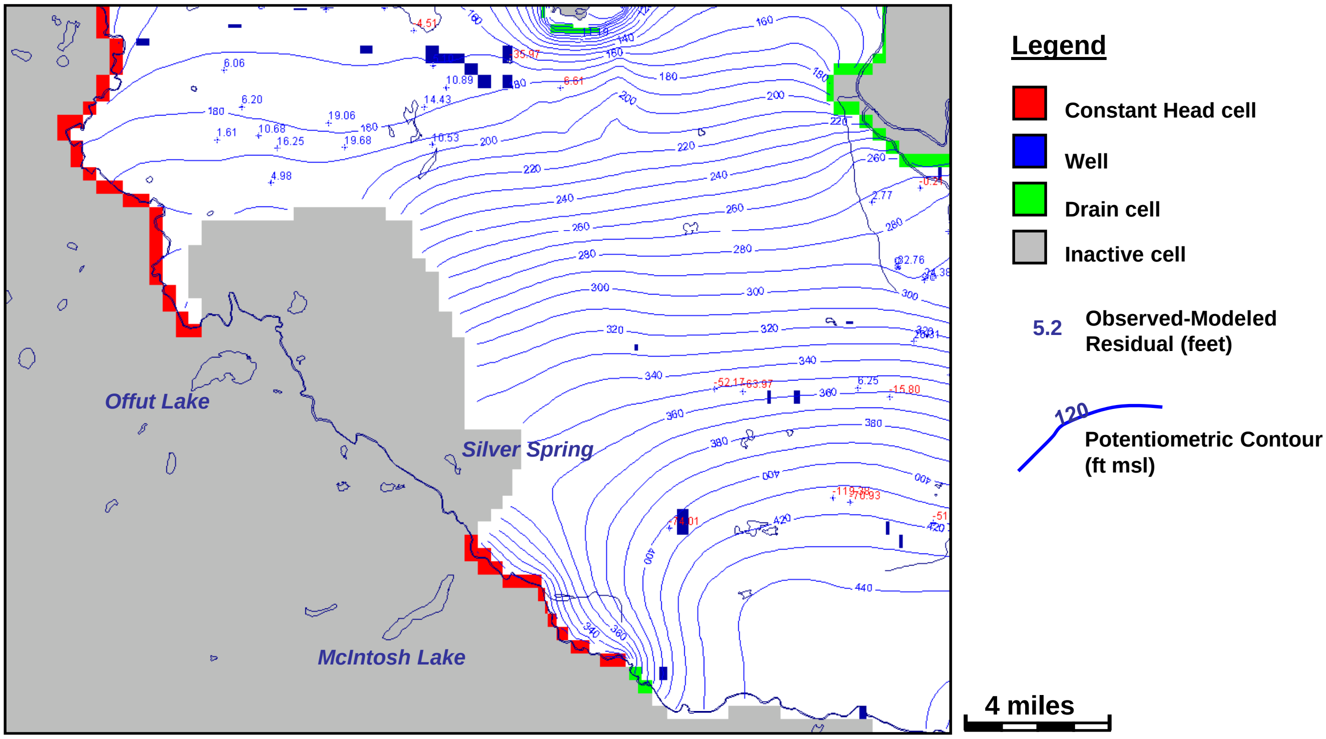

Golder Associates

City of Yelm – Future SW Yelm Wellfield Simulations

TITLE **Previous Model – Steady-state Potentiometric Heads (Layer 3)**

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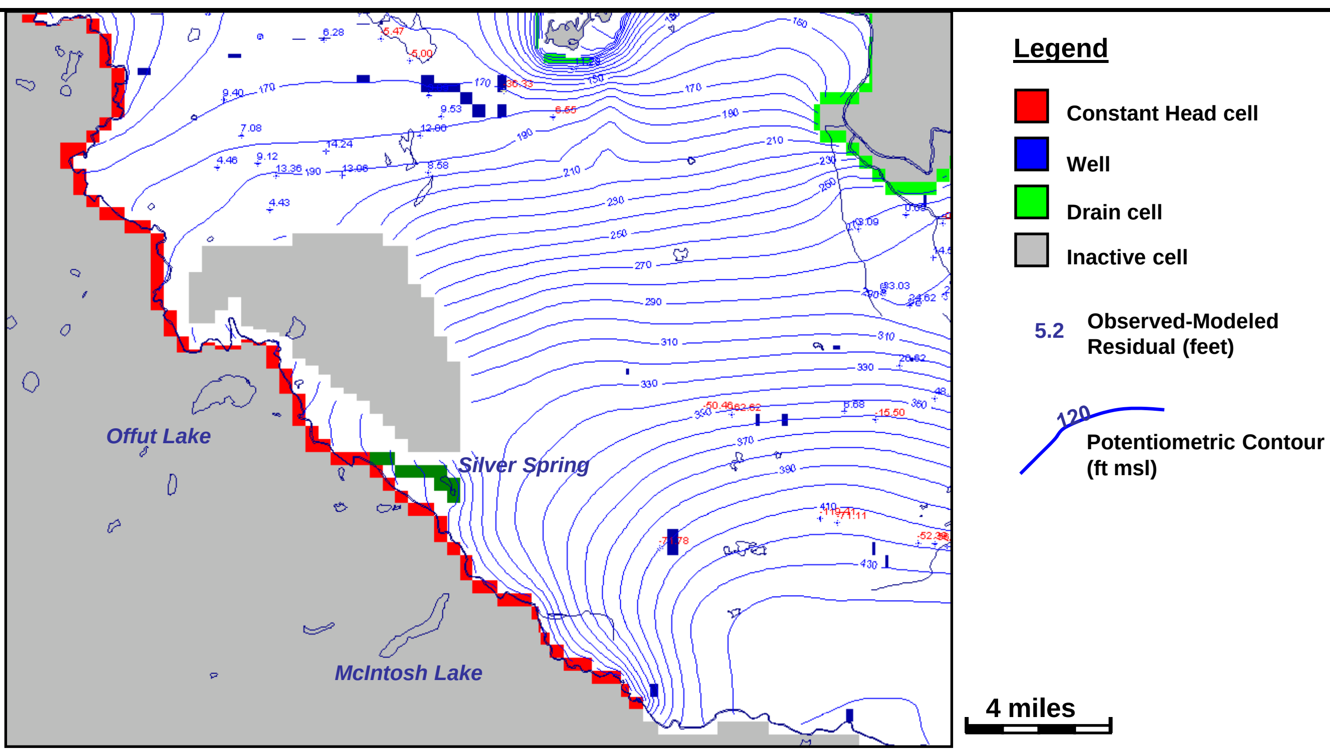
REVIEWED	JS	FILE No.		FIGURE No.	3-15



Golder Associates

City of Yelm – Future SW Yelm Wellfield Simulations

TITLE **Updated Model – Steady-state Potentiometric Heads (Layer 3)**

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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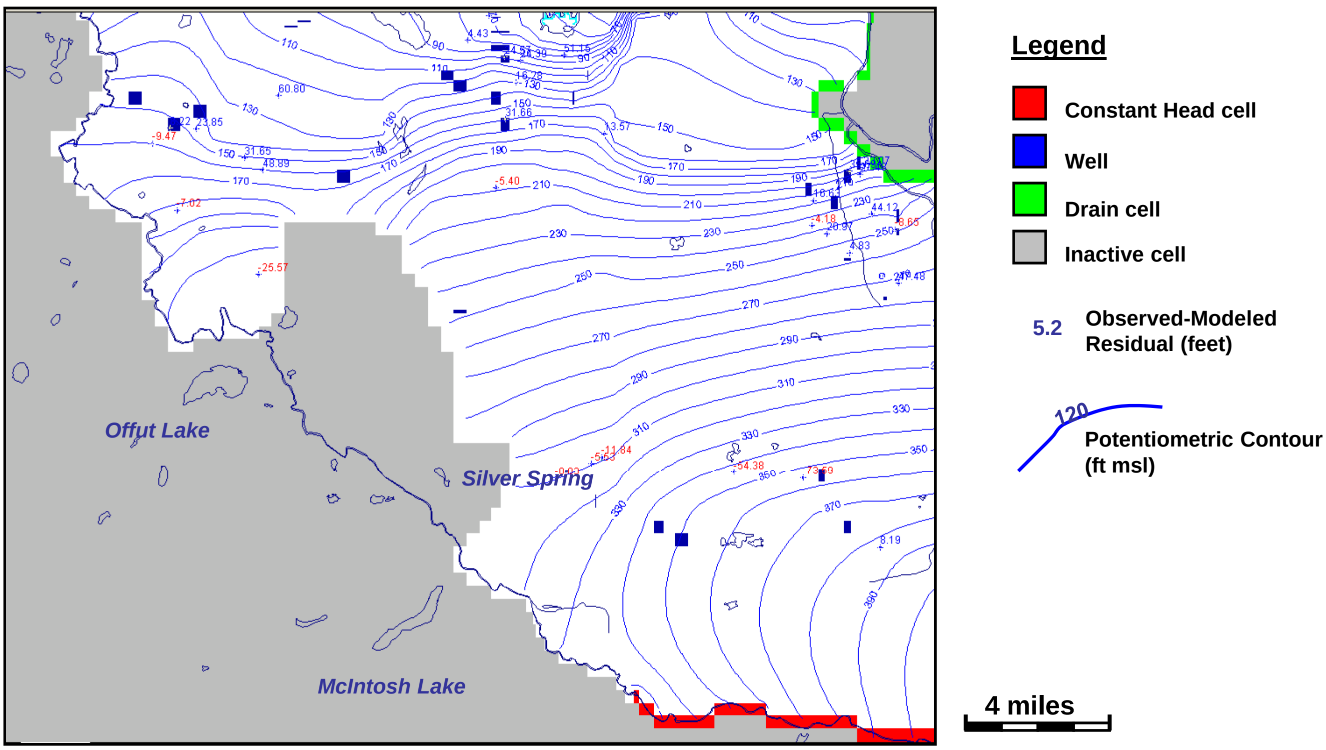

Golder Associates

City of Yelm – Future SW Yelm Wellfield Simulations

TITLE **Previous Model – Steady-state Potentiometric Heads (Layer 5)**

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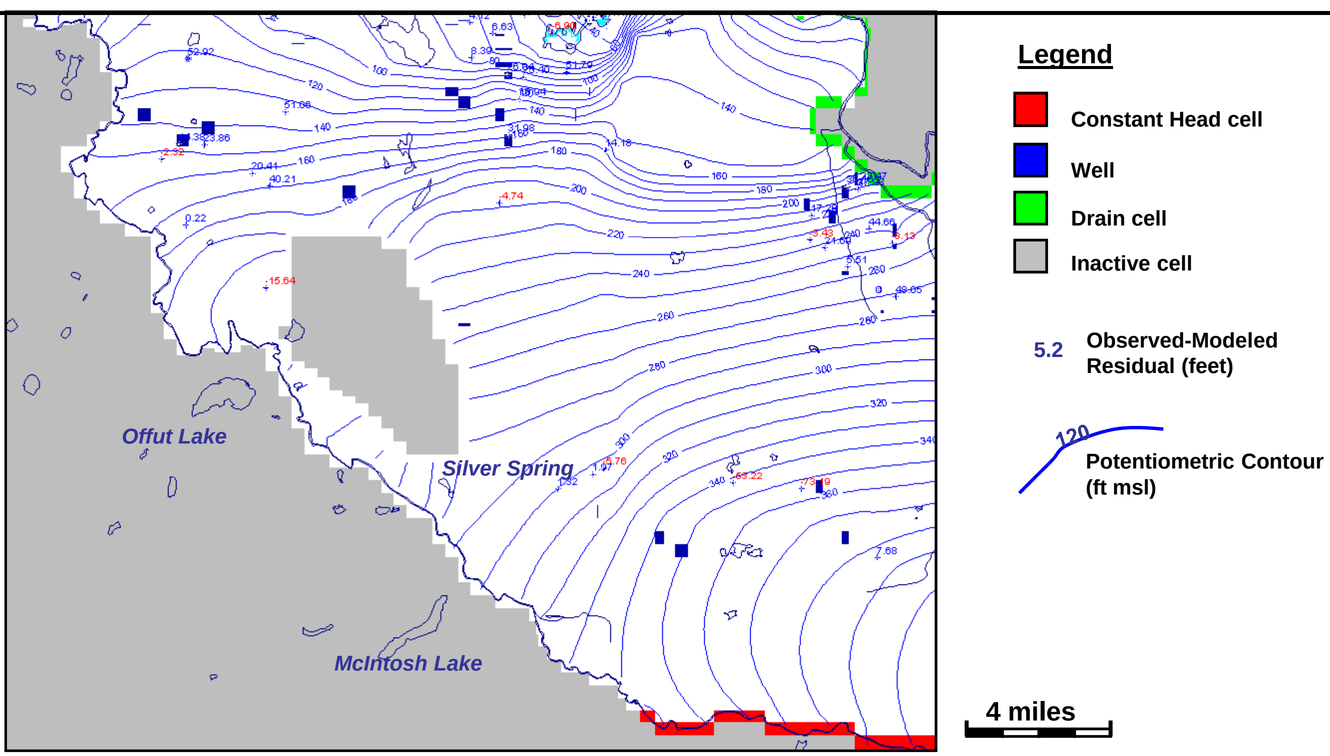

Golder Associates

City of Yelm – Future SW Yelm Wellfield Simulations

TITLE **Updated Model – Steady-state Potentiometric Heads (Layer 5)**

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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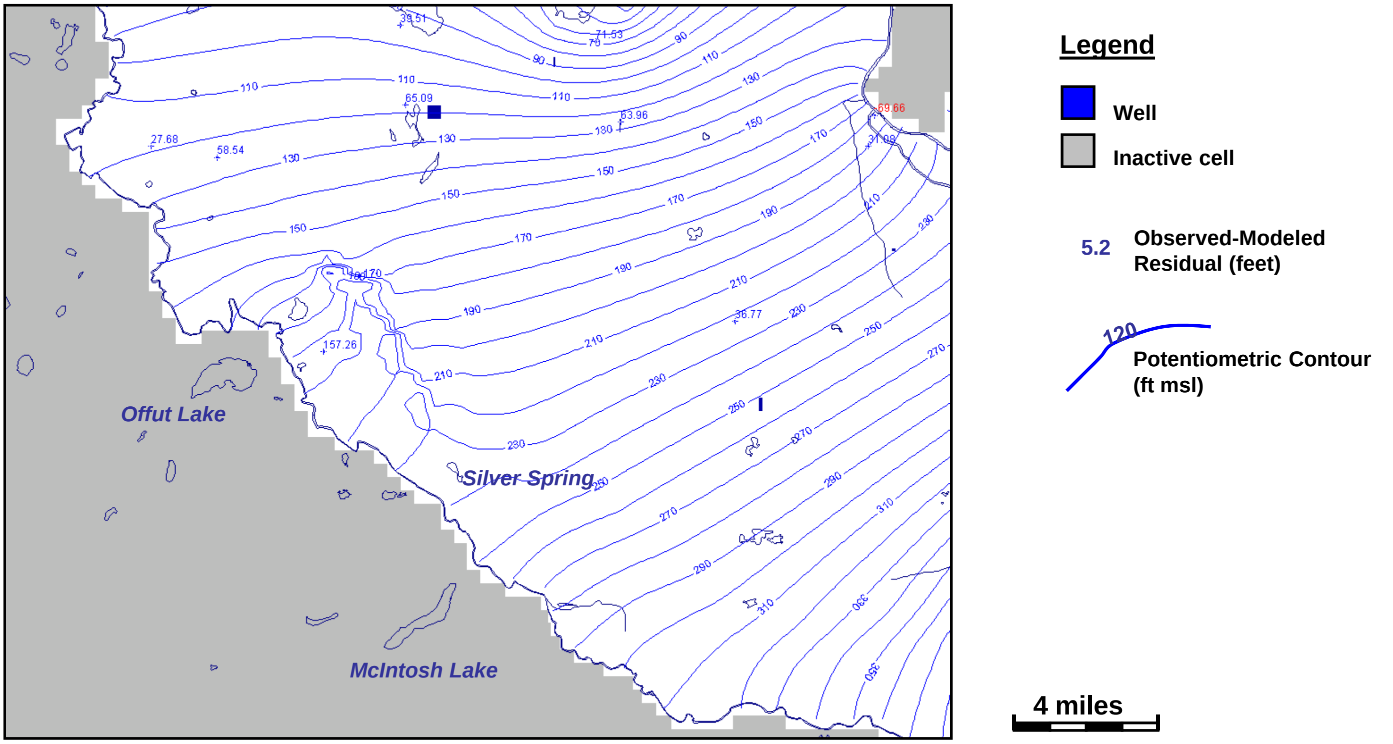

Golder Associates

TITLE

Previous Model – Steady-state Potentiometric Heads (Layer 8)

City of Yelm – Future SW Yelm Wellfield Simulations

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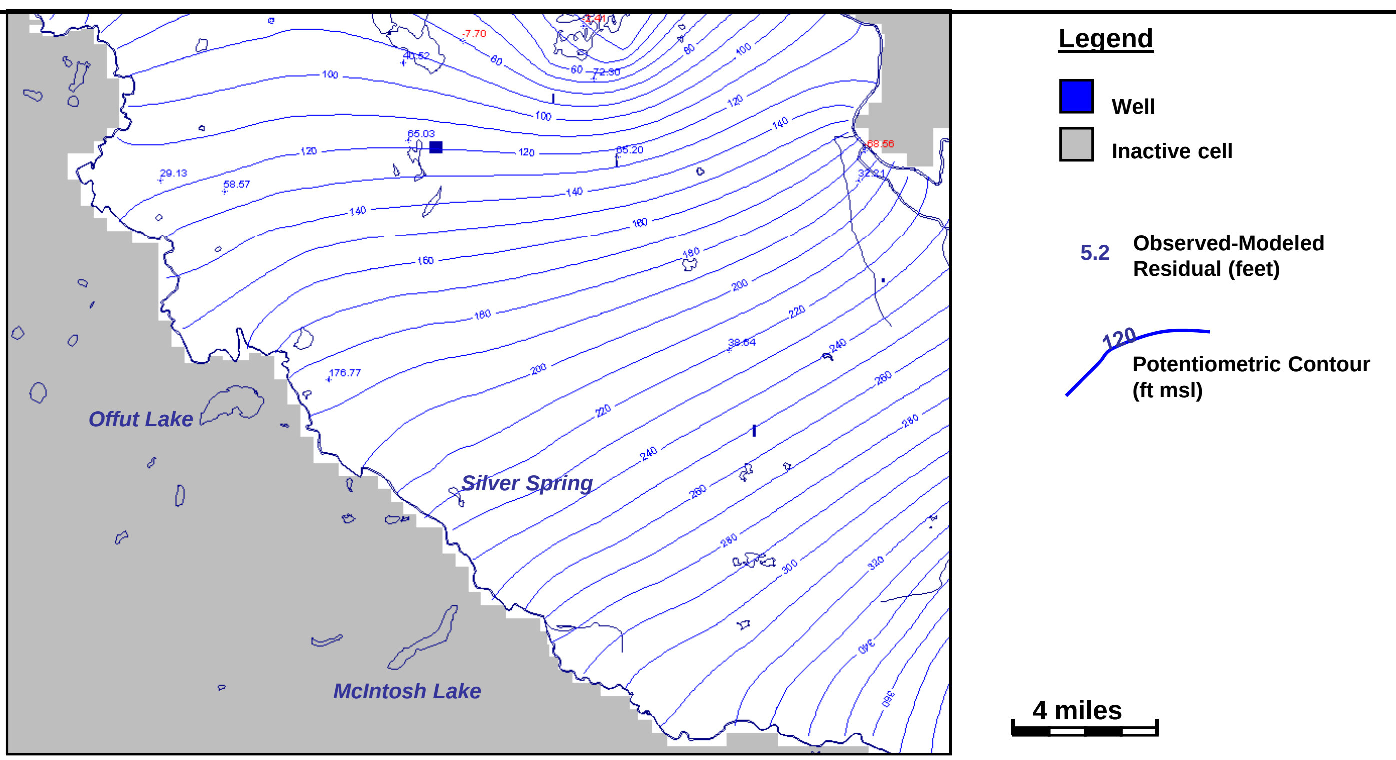

Golder Associates

TITLE

Updated Model – Steady-state Potentiometric Heads (Layer 8)

City of Yelm – Future SW Yelm Wellfield Simulations

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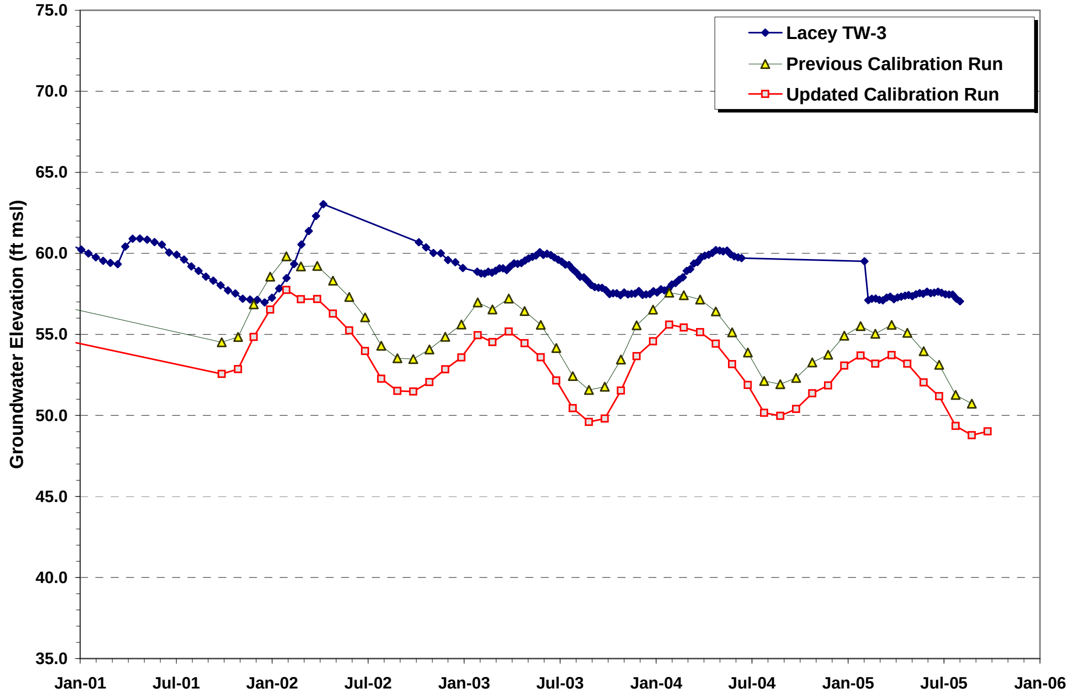

Golder Associates	TITLE **Transient Calibration Heads – Lacey's Well TW-3**		
City of Yelm – Future SW Yelm Wellfield Simulations	DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
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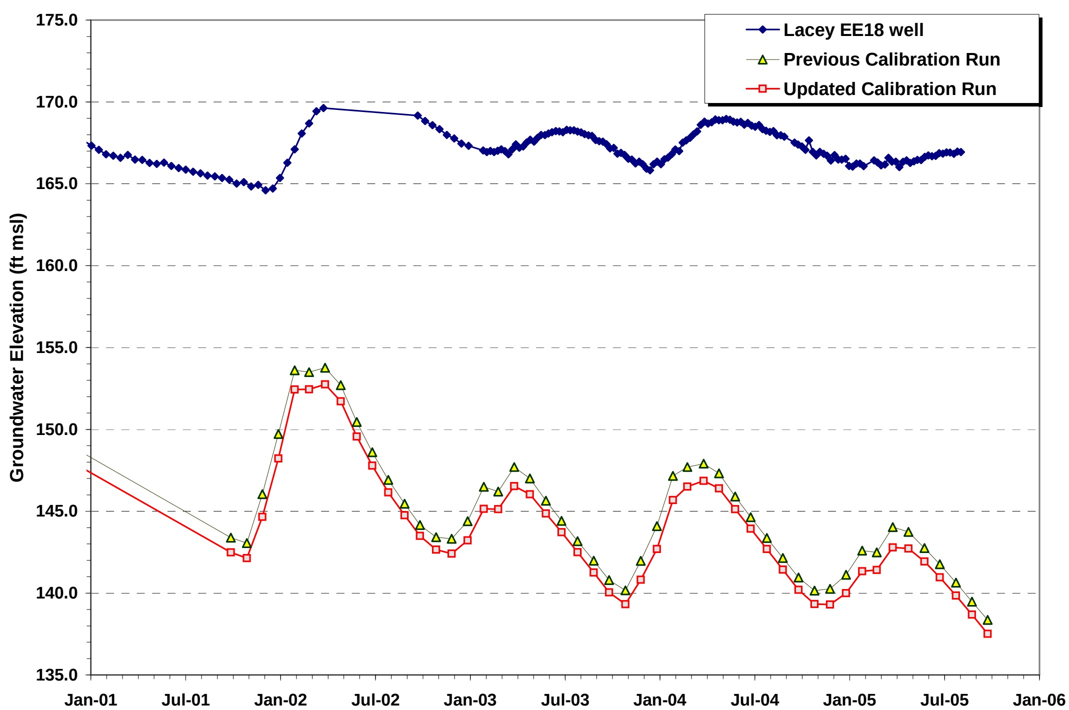

Golder Associates	TITLE **Transient Calibration Heads – Lacey's Evergreen Estates Well 18**		
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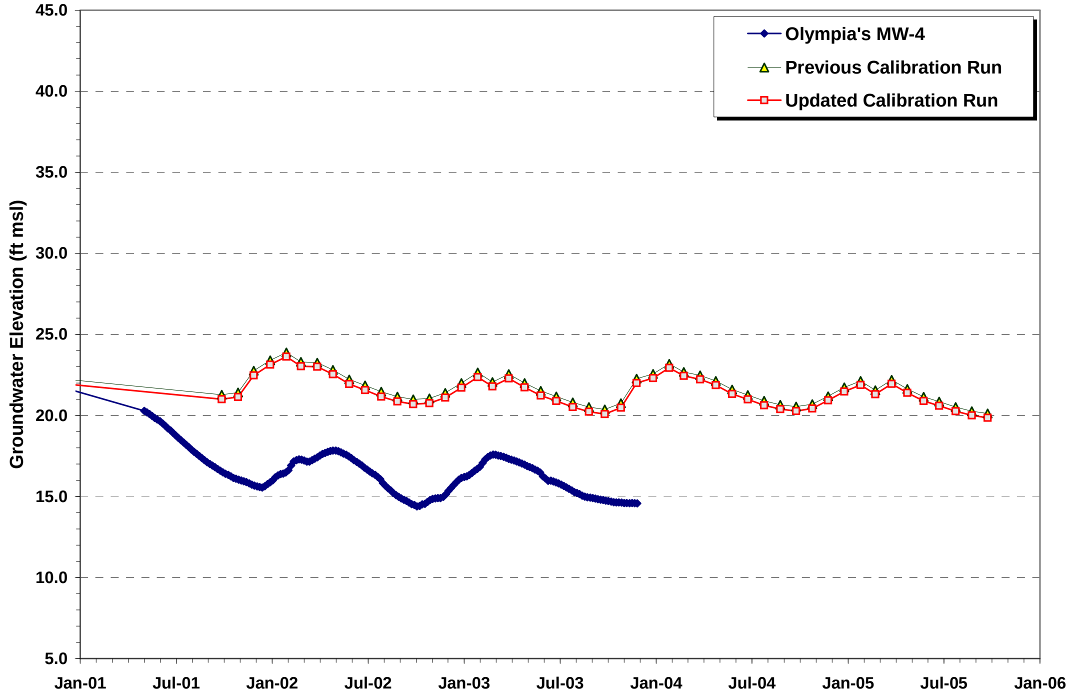

Golder Associates

TITLE

Transient Calibration Heads – Olympia's Well MW-4

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
CHECKED PAB	SCALE	DWG No.
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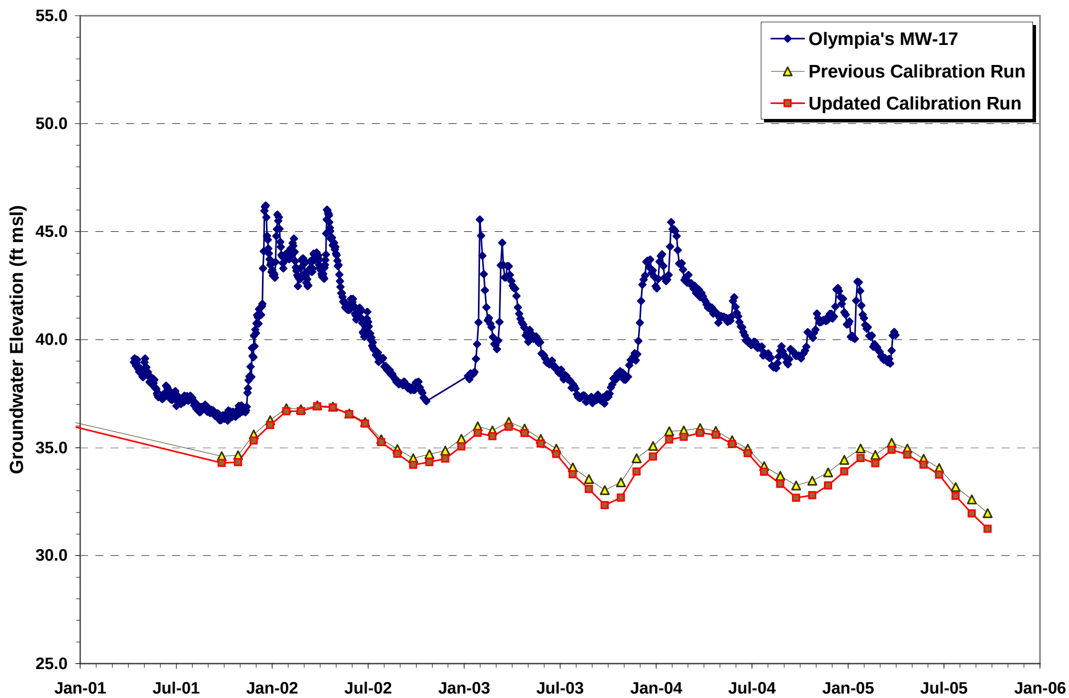

Golder Associates

TITLE

Transient Calibration Heads – Olympia's Well MW-17

City of Yelm – Future SW Yelm Wellfield Simulations

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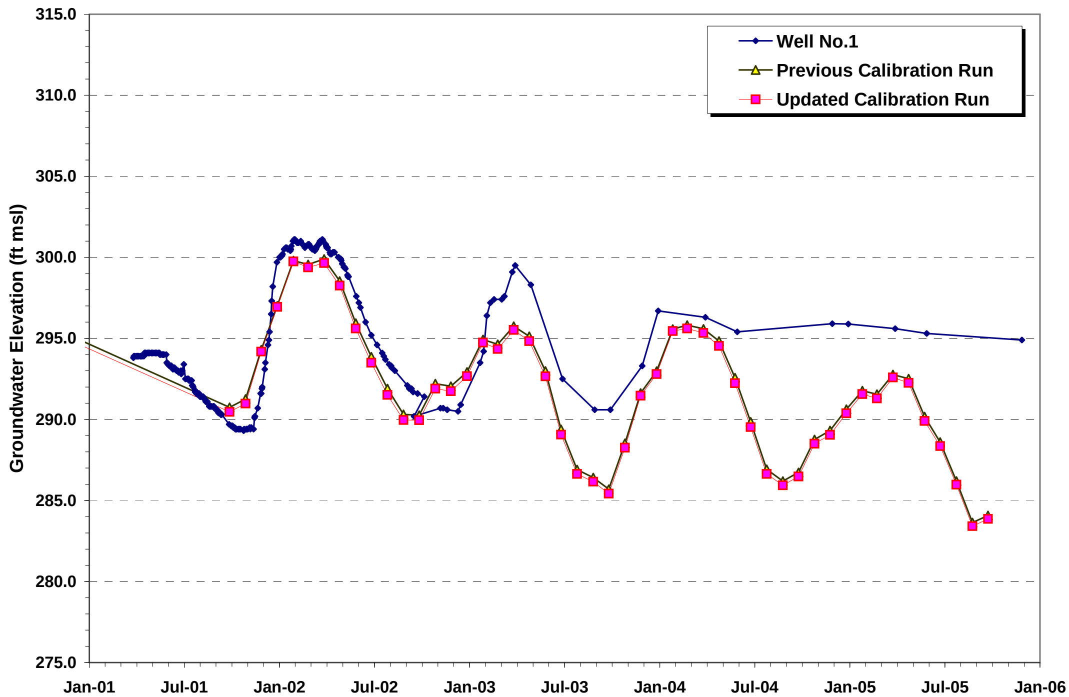
CHECKED PAB	SCALE	DWG No.
REVIEWED JS	FILE No. Sims_figs_port.ppt	FIGURE No. 3-24



Golder Associates

City of Yelm – Future SW Yelm Wellfield Simulations	TITLE Transient Calibration Heads – Yelm's Well No.1 (2001-05)		
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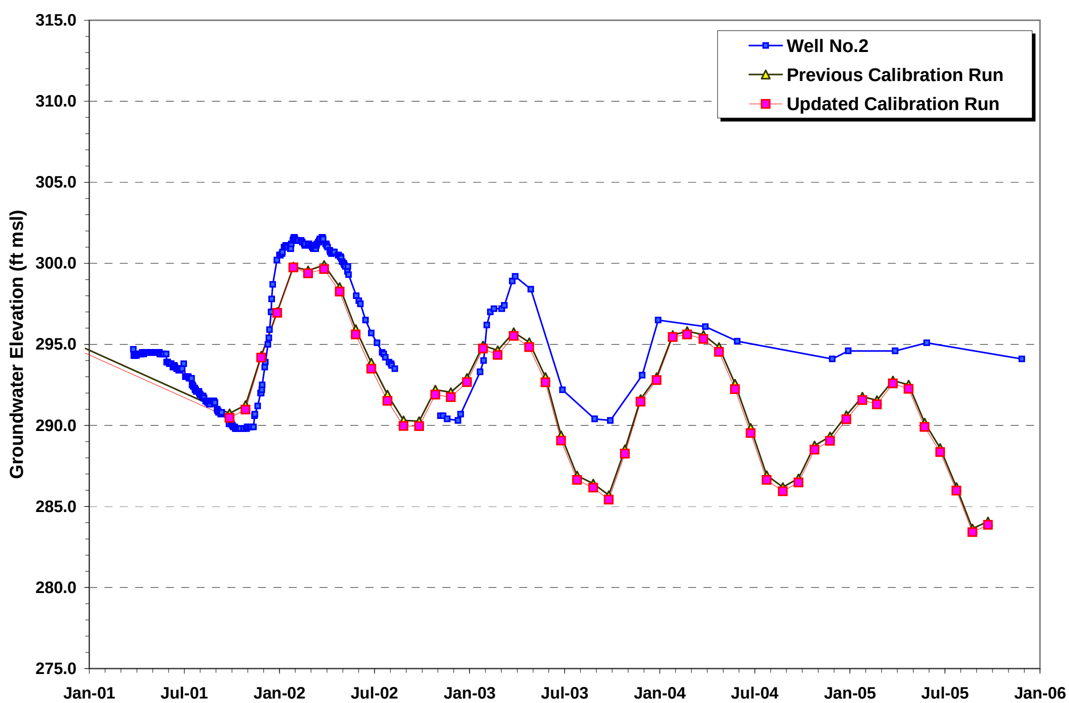

Golder Associates

City of Yelm – Future SW Yelm Wellfield Simulations	TITLE Transient Calibration Heads – Yelm's Well No. 2 (2001-05)		
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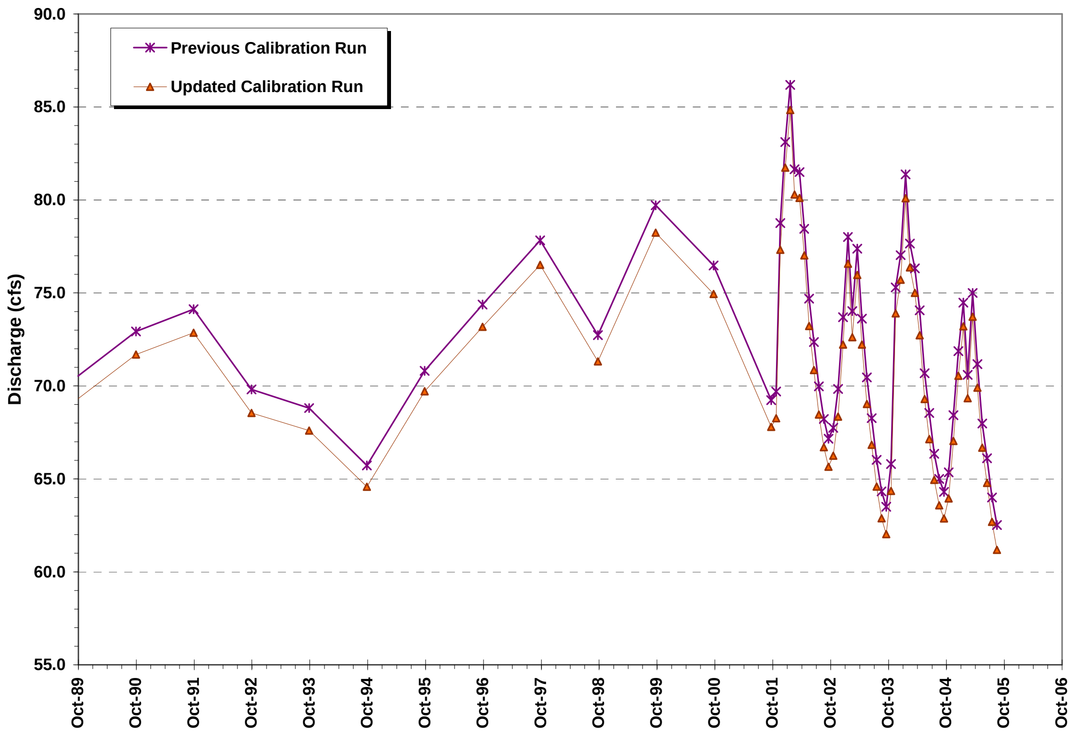
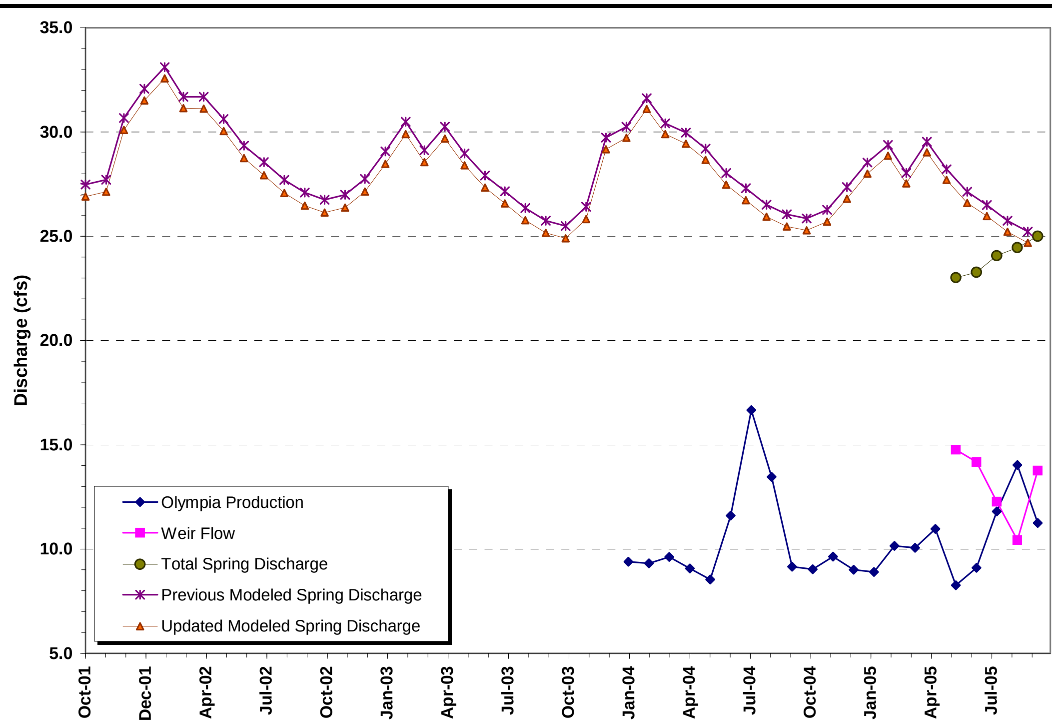


Golder Associates

TITLE **Transient Calibration Discharge – Upper McAllister Valley Discharge 1989-2005**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.	Sims_figs_port.ppt	FIGURE No.	3-27

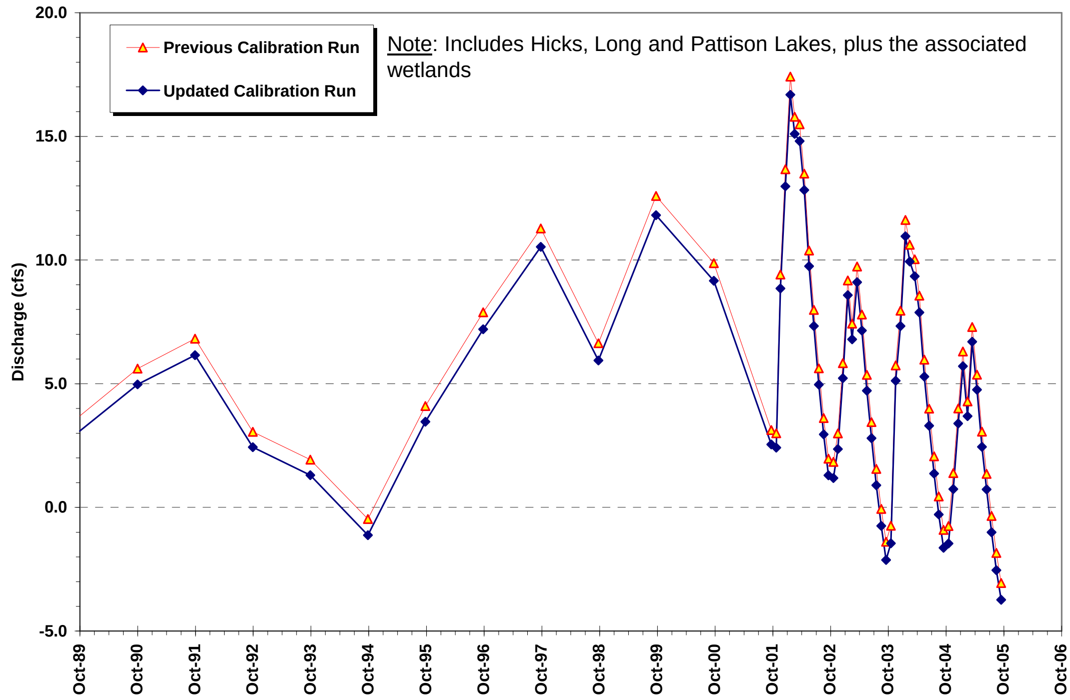


Golder Associates

TITLE **Transient Calibration Discharge – McAllister Spring Discharge 2001-05**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.	Sims_figs_port.ppt	FIGURE No.	3-28



Golder Associates

TITLE

Transient Calibration Discharge – Tri-lakes Hydrology 1989-2005

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
CHECKED PAB	SCALE	DWG No.
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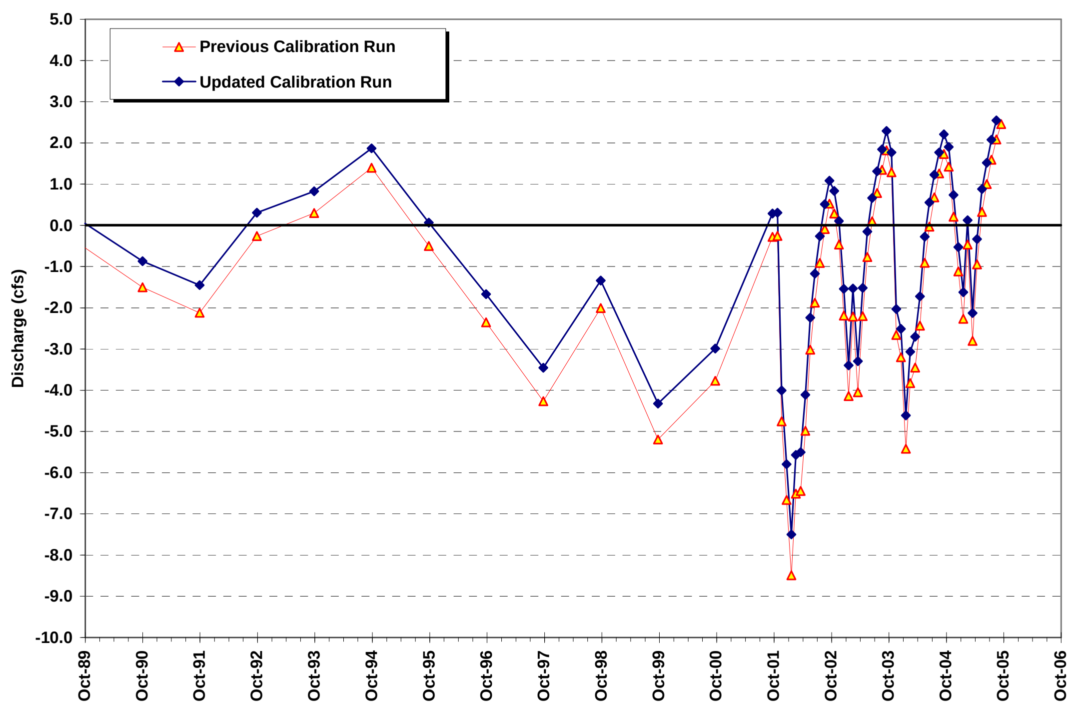

Golder Associates

TITLE

Transient Calibration Discharge – Yelm Creek 1989-2005

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
CHECKED PAB	SCALE	DWG No.
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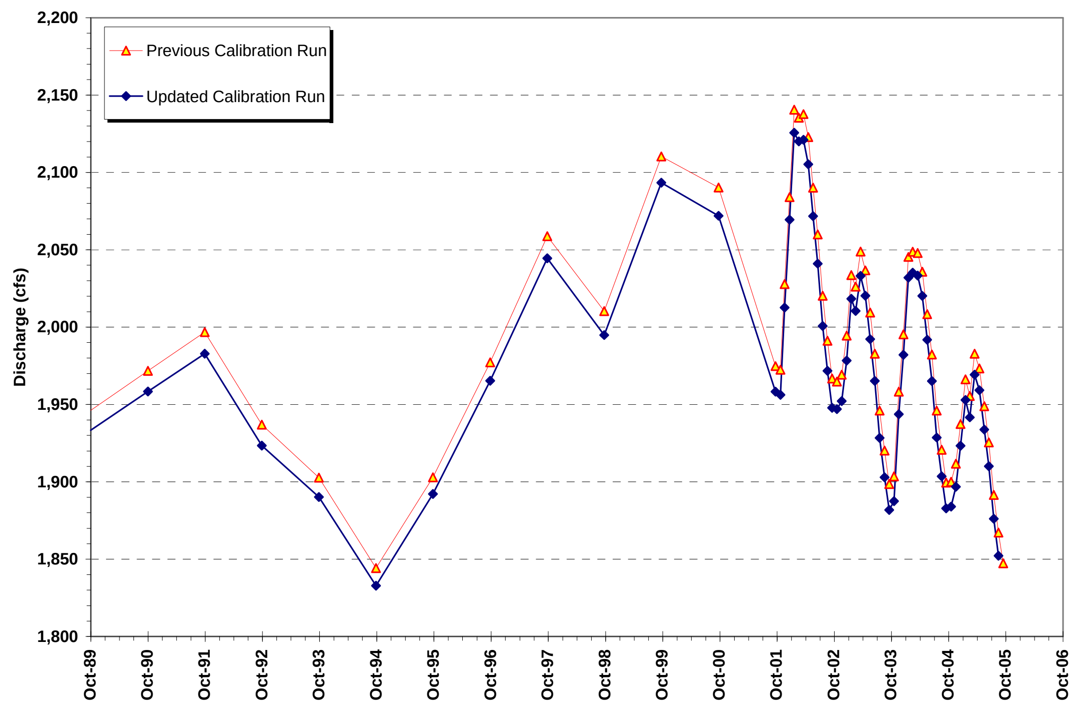

Golder Associates

TITLE

Transient Calibration Discharge – Kalama Spring 1989-2005

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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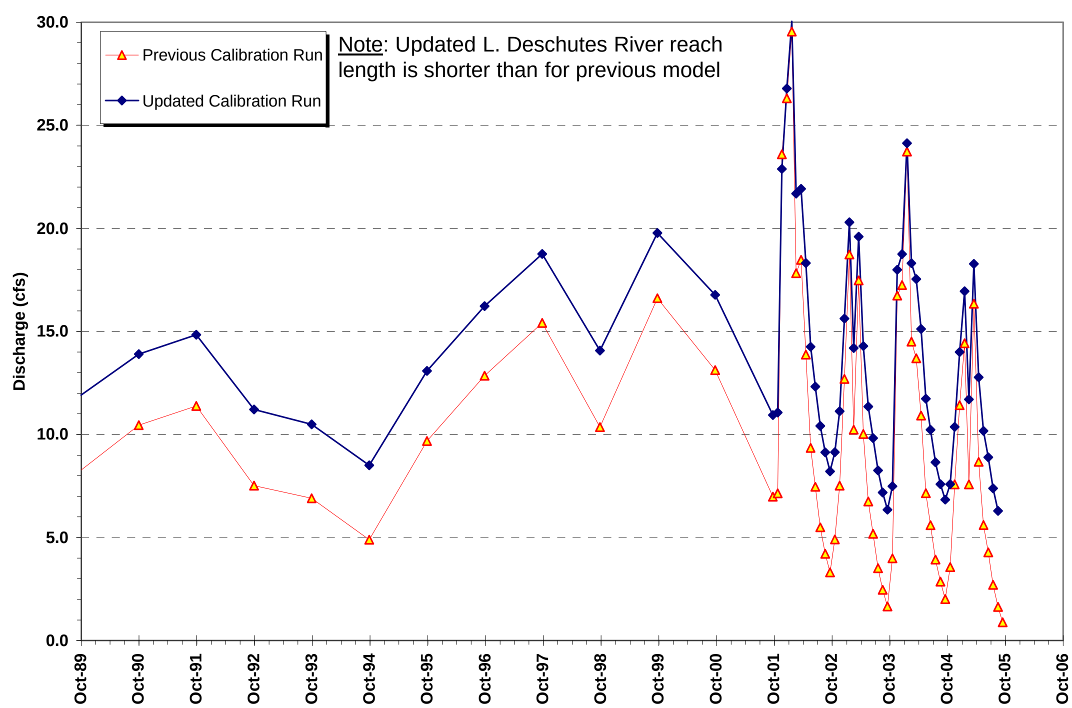


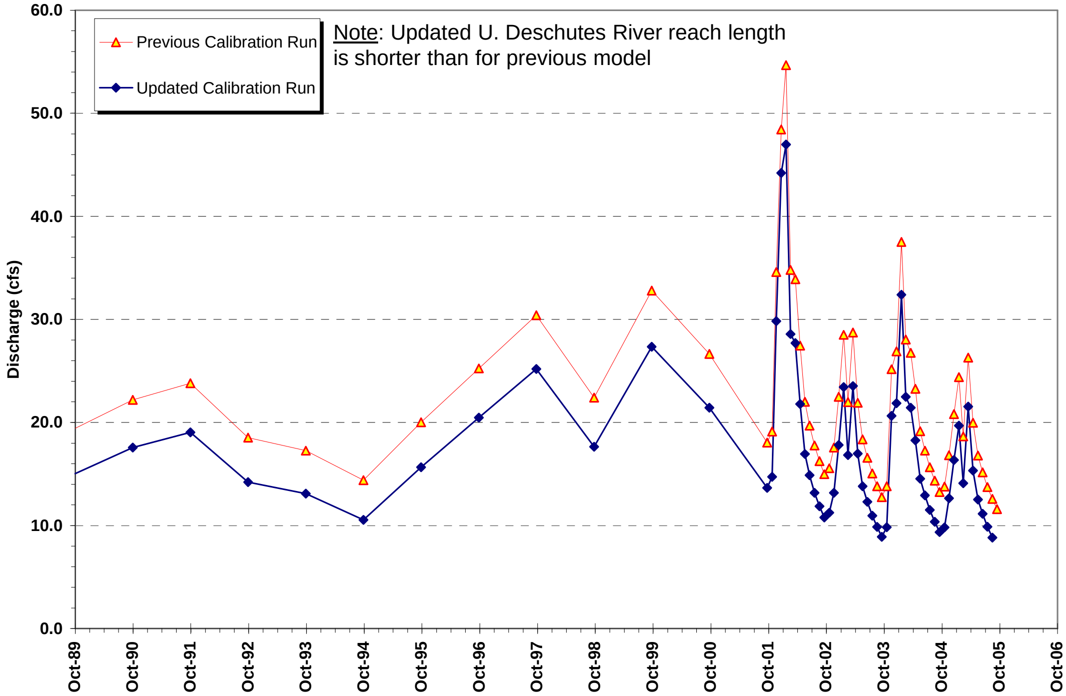
Golder Associates

TITLE

Transient Calibration Discharge – L. Deschutes River 1989-2005

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.	Sims_figs_port.ppt	FIGURE No.	3-32



Golder Associates

TITLE

Transient Calibration Discharge – U. Deschutes River 1989-2005

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
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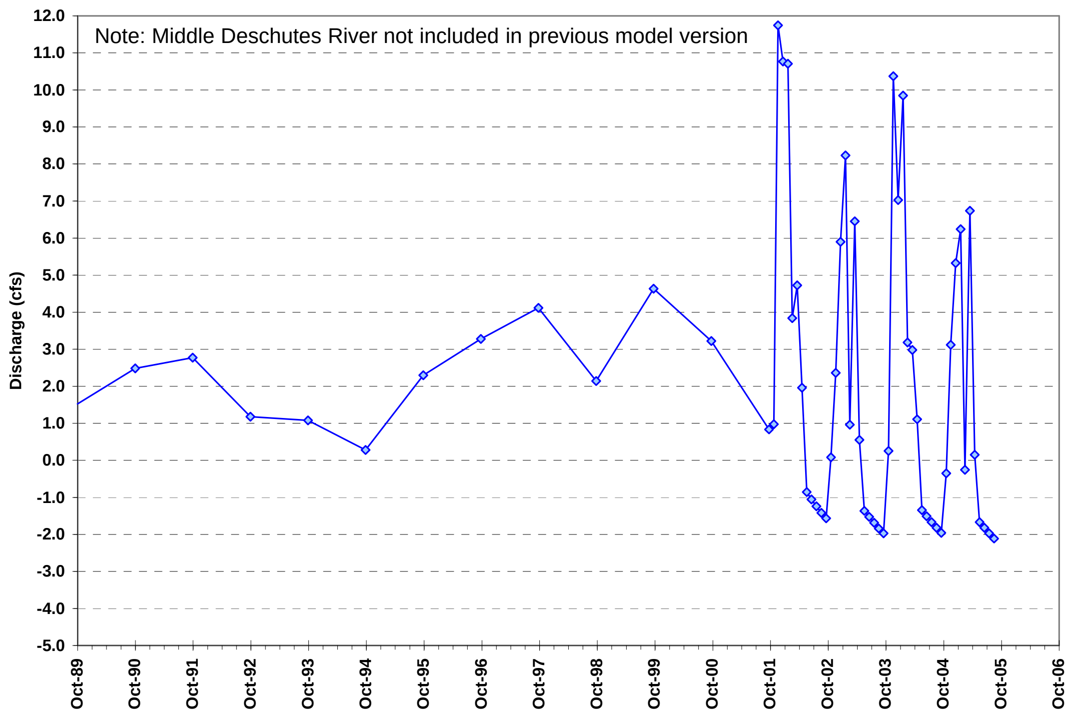


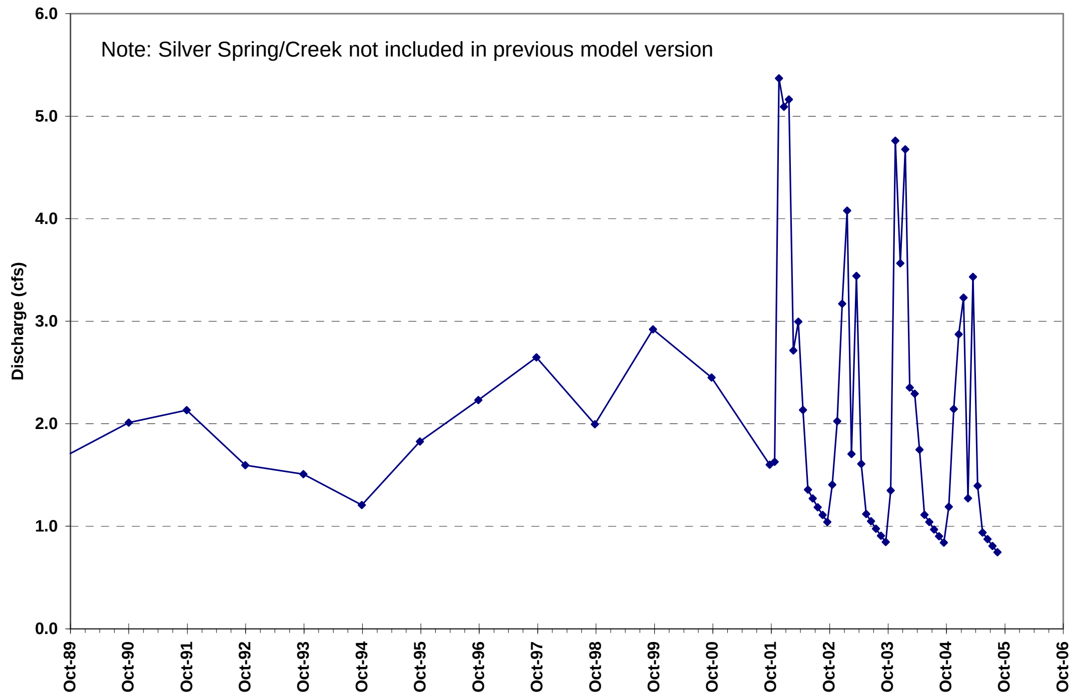
Golder Associates

TITLE

Transient Calibration Discharge – M. Deschutes River 1989-2005

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.	Sims_figs_port.ppt	FIGURE No.	3-34



Golder Associates

TITLE

Transient Calibration Discharge – Silver Spring and Creek 1988-2005

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
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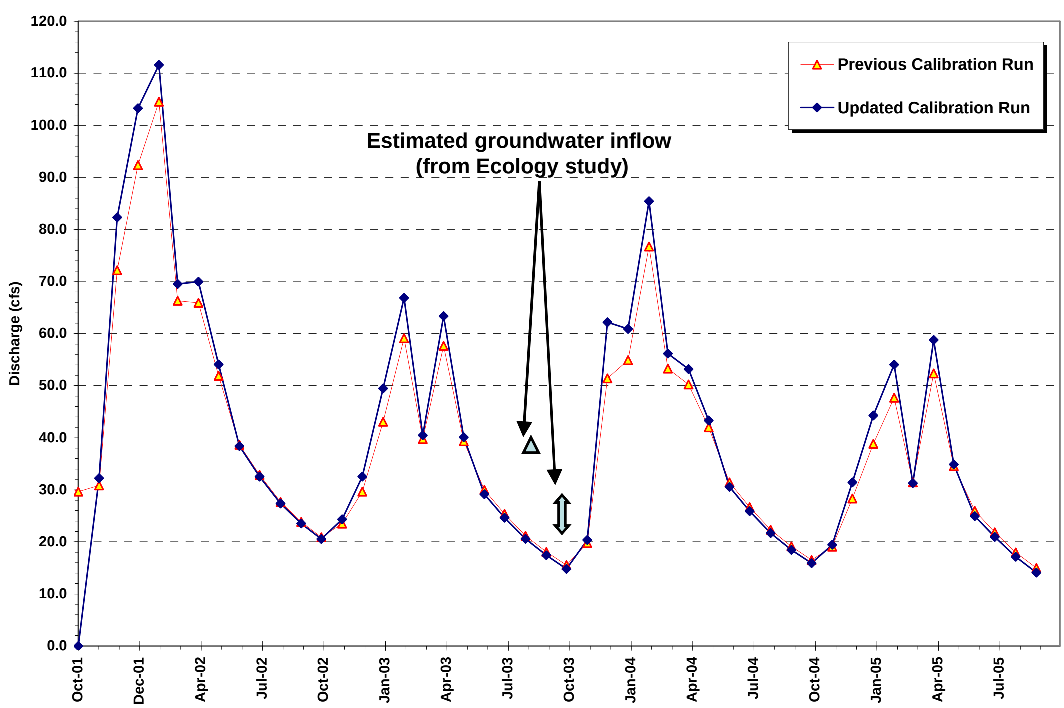


Golder Associates

TITLE

Transient Calibration Discharge – Total Deschutes River 2001-05

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.	Sims_figs_port.ppt	FIGURE No.	3-36

4.0 REVISED WELLFIELD SIMULATIONS

4.1 Introduction

This section presents the approach and results from using the updated McAllister model to simulate two, long-term future groundwater pumping scenarios that the City is considering to meet future water demand. Both cases involve development of a new wellfield, to be located west of the downtown area in what is known as the SW Highlands development area.

As described earlier, the model simulates groundwater flow at numerous surface hydrologic features, including the main components of the McAllister Valley, the major rivers (Nisqually and Deschutes), and numerous lakes and internal creeks. The main purpose of this assessment is to predict how the proposed changes in groundwater pumping will affect the groundwater discharge rates at these features. The specific list of features evaluated is included in Table 3-4.

The modeling approach used was the same used in earlier assessments, and involved initially establishing a baseline case that represents current hydrogeologic conditions in the model area. The changes in groundwater pumping are then made to the baseline case, the model is re-run and the predicted changes in groundwater flow at the key features and levels at specific wells are calculated.

Both scenarios and the New Baseline cases were simulated using the same method that was employed for previous wellfield simulations. This involved using monthly stress periods, with each annual cycle repeated a total of six times to identify any numerical instability and to attain a quasi steady-state condition. On the completion of the runs, both the water levels at key wells and discharge rates at the key hydrologic features were compared to those generated by the New Baseline case to assess the hydraulic effect of each scenario.

4.2 New Baseline Case

The New Baseline incorporates the best estimates of current hydrologic and average recharge conditions, and groundwater pumping at the main existing wells. No other changes were made to the updated calibrated version of the model. The following Sections 4.2.1 through 4.2.6 summarize the main components of the New Baseline.

4.2.1 Yelm Pumping

Yelm's downtown wells have a combined annual water right amount of 676 acre-feet (Figure 4-1). The city operates its pumping system at a combined peak capacity of 1,200 gallons per minute (gpm). Golder used the most recent six years of monthly pumping to develop a Baseline case seasonal distribution for pumping the 676 afy. This pattern is similar to other municipal pumping in the region.

4.2.2 City of Lacey

The total Baseline case pumping for Lacey remained unchanged from the original version of the model (Golder, 2006), and consists of pumping a total of 6,814 afy from 20 wells. The wells have been simulated to pump at either a uniform rate throughout the year or at a variable rate with a distinct summer peak. The simulated combined peak monthly pumping rate (in August) for all Lacey wells was 7,699 gpm (Figure 4-2).

4.2.3 City of Olympia

Olympia currently operates only one of the three wells that form their East Olympia Wellfield area. This is the Shana Park well. The other two wells (Hoffman and Indian Summer) have been essentially inactive during the last few years. The previous Baseline case included pumping for both the Shana Park and Hoffman wells. For the New Baseline, the Hoffman well pumping was set to zero and the Shana Park well pumping was revised to reflect average conditions for the period 1997 to 2005 (Figure 4-3). No pumping was included in the New Baseline for Olympia's planned 26 mgd capacity wellfield (to be located up-gradient from McAllister Spring) or the new Briggs well.

Olympia operates several wells that are located in their Eastern Pressure Zone. The groundwater pumping included in the Baseline case for Olympia remained unchanged from the original version, and does not include the planned 20 million gallons per day (mgd) capacity wellfield up-gradient from McAllister Spring. It is anticipated that the model revisions will be required to represent the changes to the total groundwater pumping (and changes to projected impacts) when Olympia's planned wellfield is developed. .

4.2.4 Other Pumping

The Baseline case pumping for all other wells in the model area remained unchanged from the original version of the model. These wells include numerous private wells and some small public systems. Figure 4-4 shows the pumping simulated for the Dragt, Nisqually Golf Course and McMonigle pumping wells in the Yelm area for the New Baseline case.

4.2.5 Precipitation-derived Recharge

The annual precipitation-derived recharge for the New Baseline case was the same as simulated for the steady-state calibration (based on the long-term average hydrologic conditions). The seasonal distribution of recharge was also the same as used in the modeling for Olympia and Lacey (Golder, 2006) and was based on assigning recharge only during the months from November to April, inclusive.

4.2.6 Artificial Recharge

Yelm recharges 56 afy of reclaimed water at the Cochrane Memorial Park facility, located close to the downtown area. For the purpose of the Baseline case, this annual rate was maintained with a uniformly distributed flux (equal in all months of the year).

4.3 Wellfield Scenarios

The specific details of the two wellfield cases that were simulated using the model are as follows (Table 4-1).

4.3.1 Case A - New SW Yelm Wellfield Only (Figure 4-5)

- Produce all 4,186 afy from a new Yelm wellfield that consists of five wells installed in the upper portion of the TQu aquifer, with equal pumping rates of 837 afy. The monthly average peak pumping (in August) will be 4,345 gpm.
- Retire Yelm's existing downtown pumping (676 afy at Yelm No.1 and No.2), the existing pumping for Dragt (totaling 189 afy) and the Nisqually Golf Course (totaling 151 afy).
- Maintain the currently-permitted pumping at the McMonigle water right, totaling 318.8 afy, consisting of 294.19 afy of irrigation, 16.8 afy of stock and 7.81 afy of domestic supply.

4.3.2 Case D – Hybrid New Wellfield/Existing Downtown Facilities (Figure 4-6)

- Transfer the allowable Dragt right (155.66 afy) to Yelm's two downtown wells, for a total of 831.66 afy. All downtown well pumping will use Yelm's typical municipal seasonal pattern. The peak combined monthly pumping for the downtown wells will be 863 gpm (in August).
- Transfer 143.46 afy (or 95 percent) of the existing Nisqually Golf Course irrigation water right (totaling 151 afy) to Yelm, to be pumped from a new well located adjacent to the Golf Course well completed in the Advance Outwash aquifer. Also, transfer 172.96 afy from the McMonigle irrigation water right to the same new well. The seasonal pumping pattern for this new well will be the same as for the downtown wells, with a peak rate in August of 328 gpm.
- Produce the remaining 3,037.88 afy from a new SW Yelm wellfield, consisting of four wells installed in the upper part of TQu unit, with equal peak pumping rates of 788 afy in August. The combined peak summer pumping for the four wells will be 3,153 gpm.

Figure 4-7 shows the possible wellfield layout for Case A. Case D arrangement would be the same as for Case A, but without the central well (SW Yelm No. 5).

TABLE 4-1

City of Yelm Pumping Totals for Scenarios

Scenario	City of Yelm				Other Local Pumping		
	Downtown Wells	New GC Well	SW Wellfield(2)	Total Yelm	Dragt	Nisqually GC	McMonigle
Baseline	676	0	0	676	119[1]	151	318.8(3)
Case A	0	0	4,186	4,186	0	0	82.8
Case D	831.66	316.46	3,037.88	4,186	0	0	82.8

Notes: (1) – excludes the surface water right of 70 afy (total water right is 189 afy); (2) –Case A uses 5 wells, Case D uses 4 wells; (3) – consists of three wells, irrigation/stock/domestic uses. These rates are preliminary, and have been developed for initial planning purposes only.

4.4 Scenario Results

The model results include changes in (1) groundwater discharge rates to the key hydrologic features, and (2) groundwater levels at key wells in the area.

4.4.1 Groundwater Discharge Impacts

Tables 4-2 through 4-5 summarize the model-predicted changes in groundwater discharge rate at the key hydrologic features for the two cases versus the Baseline case. Tables 4-4 and 4-5 present changes for individual reaches, and Table 4-3 and 4-5 present cumulative impacts at specific points within the watershed.

4.4.1.1 Case A

Case A eliminates 708 afy of pumping from the shallow aquifers (that directly support flows in the main surface water features in the Yelm area) while increasing pumping in the deeper part of the aquifer system by 4,186 afy. The overall net increase in local pumping compared to the Baseline case is 3,240 afy.

Yelm Creek and Nisqually Valley (Figures 4-8 through 4-13)

The modeling predicts that producing the full 4,186 afy from the proposed new wellfield (while eliminating the current downtown Yelm wells, the Dragt and Nisqually Golf Course production) would result in a net increase in groundwater discharge to Yelm Creek and the upper Nisqually River throughout the year, with maximum increases of 0.24 cfs and 0.25 cfs, respectively. Both maximum increases are predicted to occur in the summer. The cumulative effect of these increased flows in the Nisqually River where Thompson Creek enters would be between 0.29 cfs and 0.50 cfs (in August).

The groundwater discharge to the middle and lower reaches of the Nisqually River would be reduced by up to 0.21 and 0.37 cfs, respectively (both in summer). Accounting for the predicted increase in flows in the upper Nisqually reach mentioned above, the net decrease in flow at RM 4.3 would be between 0.06 cfs (in June) and 0.19 cfs (in October). These represent flow reduction of up to 0.3 percent compared to the Baseline case rate.

Deschutes Valley (Figures 4-14 through 4-17)

The maximum seasonal depletions to the upper, middle and lower reaches of the Deschutes River would be 0.76 cfs, 0.15 cfs and 0.1 cfs, respectively. The model also predicts discharge decreases to the tributary Silver Spring and Spurgeon Creek of up to 0.06 cfs and 0.22 cfs, respectively. The predicted cumulative decrease in flow at Tumwater Falls is between 0.79 cfs (in May) and 1.23 cfs (in February through March).

McAllister Valley (Figures 4-18 and 4-19)

The combined maximum depletion to the upper McAllister Valley hydrology is predicted to be 0.91 cfs, which will occur in August. This equates to a reduction in total groundwater discharge by 1.4 percent.

Woodland Creek Basin

Although the model-predicted impact to discharge directly to Woodland Creek is relatively small (up to 0.01 cfs), impacts are predicted to flow supporting the tri-lakes from which Woodland Creek originates. The maximum depletion to the lakes and associated wetlands is 0.1 cfs (in September). The cumulative impact on flow in the creek at Henderson Inlet ranges from 0.09 to 0.11 cfs.

TABLE 4-2

Predicted Changes in Groundwater Discharge versus Baseline for Case A

Hydrologic Area/Feature	Highest Seasonal Discharge Change			Summer Discharge Change	
	cfs	*%*	*month(s)*	*cfs*	*%*
Yelm Creek	+0.24	18.3	Aug	+0.24	18.3
Nisqually River					
- Upper reach	+0.25	1.2	Aug	+0.25	1.2
- Kalama Creek Spring	-0.08	1.8	Aug	-0.08	1.8
- Middle reach	-0.21	1.5	Aug	-0.21	1.5
- Lower reach (15,000-ft above RM4.3)	-0.37	1.6	Aug-Sep	-0.37	1.6
Deschutes River					
- Upper reach	-.076	2.2	Mar	-0.59	5.5
- Middle reach	-0.15	1.6	Sep	-0.15	1.6
- Silver Creek/Spring	-0.06	6.1	Aug	-0.06	6.1
- Spurgeon Creek	-0.22	1.5	Feb	-0.14	5.2
- Lower reach	-0.10	0.4	Feb-Mar	-0.07	1.0
McAllister Valley					
- McAllister Spring	-0.39	1.5	Aug-Sep	-0.39	1.5
- Other upper valley springs	-0.51	1.5	Aug	-0.51	1.5
- McAllister Creek	<0.01	<0.1	*	<0.01	<0.1
- Valley-bluff springs	-0.01	0.2	Feb-Sep	-0.01	0.2
Upland Lakes and Creeks					
- Lake St. Clair	-0.01	1.3	*	-0.01	1.3
- Long-Hicks-Pattison lakes	-0.10	11.5	Sep	-0.10	11.5
- Woodland Creek	-0.01	0.2	*	-0.01	0.2

Note: All rates in cfs. Positive rates indicate monthly groundwater discharge depletion versus the baseline case. % - percentage of baseline discharge depleted. *month* – month in which highest loss would occur. Summer = Jun-Sep inclusive. * - indicates equal rate all year. ** - indicates change in net flow direction predicted.

TABLE 4-3

Predicted Cumulative Changes in Groundwater Discharge versus Baseline for Case A

Hydrologic Area/Feature	Highest Annual Discharge Change			Highest Summer Discharge Change	
	cfs	*%*	*month(s)*	*cfs*	*%*
Nisqually River					
at Thompson Creek	+0.50	2.4	Aug	+0.50	2.4
at Nisqually Indian Reservation	+0.22	0.6	Sep	+0.22	0.6
at RM 4.3	-0.19	0.3	Oct	-0.16	0.3
Deschutes River					
at Silver Creek	-0.82	2.2	Mar	-0.64	5.5
at Spurgeon Creek	-1.12	1.9	Feb-Mar	-0.93	7.9
at Tumwater Falls	-1.23	1.5	Feb-Mar	-1.00	5.0
McAllister Valley					
at Medicine Creek	-0.91	1.4	Aug	-0.91	1.4
Woodland Creek					
at Hicks Lake outfall	-0.10	11.5	Sep	-0.10	11.5
at Henderson Inlet	-0.11	0.5	Mar	-0.10	4.3

Note: Negative rates indicate monthly groundwater discharge depletion versus the baseline case. % - percentage of baseline discharge depleted. *month* – month in which highest loss would occur. Summer = Jun-Sep inclusive.

4.4.1.2 Case D

The modeling predicts that producing 4,186 afy from the new wellfield, the existing downtown wells, and the new well at the Nisqually Golf Course well (while eliminating the Dragt production at its current location) would result in depletions at several hydrologic features.

Yelm Creek and Nisqually Valley (Figures 4-8 through 4-13)

The predicted maximum depletions to Yelm Creek and the upper Nisqually reach are 0.28 and 0.35 cfs, respectively; both depletions would occur in March. The predicted maximum summer depletions are 0.19 and 0.31 cfs, respectively. The combined effect of these flow depletions at the point where Thompson Creek enters the Nisqually River is between 0.42 cfs (in September) and 0.63 cfs (in March), and represents a flow decrease compared to the Baseline case of up to 2.4 percent.

The middle and lower reaches of the Nisqually River are predicted to experience depletions of up to 0.18 and 0.28 cfs, respectively (both in August). The cumulative decrease in flow in the Nisqually River at RM 4.3 is between 1.0 cfs (in March and August) and 0.85 cfs (in May). These represent flow decreases compared to the Baseline case of up to 1.6 percent.

Deschutes Valley (Figures 4-14 through 4-17)

The maximum seasonal depletions to the upper, middle and lower reaches of the Deschutes River would be 0.59 cfs, 0.11 cfs and 0.08 cfs, respectively. The model also predicts maximum discharge decreases to the tributary Silver Spring and Spurgeon Creek of 0.05 cfs and 0.17 cfs, respectively. The predicted cumulative decrease in flow to the river at Tumwater Falls is between 0.59 cfs (in May) and 0.95 cfs (in February).

McAllister Valley (Figures 4-18 and 4-19)

The cumulative depletion to the upper McAllister Valley is predicted to be between 0.46 cfs (in April) and 0.68 cfs (in August), which equates to a decrease of the Baseline case flow of 1.1 percent.

Woodland Creek Basin

As for Case A, the model-predicted impact to discharge directly to Woodland Creek for Case D is relatively small (up to 0.01 cfs). The maximum depletion to the tri-lakes and associated wetlands is 0.07 cfs (in August). The cumulative impact on flow in the creek at Henderson Inlet ranges from 0.07 to 0.08 cfs.

TABLE 4-4

Predicted Changes in Groundwater Discharge versus Baseline for Case D

Hydrologic Area/Feature	Highest Annual Discharge Change			Highest Summer Discharge Change	
	cfs	*%*	*month(s)*	*cfs*	*%*
Yelm Creek	-0.28	5.6	Mar	-0.19	**
Nisqually River					
- Upper reach	-0.35	1.4	Mar	-0.31	1.5
- Kalama Creek Spring	-0.06	1.4	Aug	-0.06	1.4
- Middle reach	-0.18	1.3	Aug	-0.18	1.3
- Lower reach (15,000-ft above RM4.3)	-0.28	1.2	Aug	-0.28	1.2
Deschutes River					
- Upper reach	-0.59	1.7	Mar	-0.43	4.0
- Middle reach	-0.11	6.7	Jul	-0.11	6.7
- Silver Creek/Spring	-0.05	1.2	Mar	-0.04	4.6
- Spurgeon Creek	-0.17	1.2	Feb	-0.11	4.1
- Lower reach	-0.08	0.3	Feb-Mar	-0.05	0.7
McAllister Valley					
- McAllister Spring	-0.29	1.1	Aug-Sep	-0.29	1.1
- Other upper valley springs	-0.38	1.1	Aug	-0.38	1.1
- McAllister Creek	<0.01	<0.1	*	<0.01	<0.1
- Valley-bluff springs	<0.01	<0.1	*	<0.01	<0.1
Upland Lakes and Creeks					
- Lake St. Clair	-0.01	1.0	*	-0.01	<0.1
- Long-Hicks-Pattison Lakes	-0.07	10.5	Aug	-0.07	10.5
- Woodland Creek	-0.01	0.1	Nov-May	<0.01	<0.1

Note: All rates in cfs. Positive rates indicate monthly groundwater discharge depletion versus the baseline case. % - percentage of baseline discharge depleted. *month* – month in which highest loss would occur. Summer = Jun-Sep inclusive. * - indicates equal rate all year. ** - indicates change in net flow direction predicted.

TABLE 4-5

Predicted Cumulative Changes in Groundwater Discharge versus Baseline for Case D

Hydrologic Area/Feature	Highest Annual Discharge Change			Highest Summer Discharge Change	
	cfs	*%*	*month(s)*	*cfs*	*%*
Nisqually River					
at Thompson Creek	-0.63	2.0	Mar	-0.48	2.4
at Nisqually Indian Reservation	-0.81	1.6	Mar	-0.72	1.9
at RM 4.3	-1.00	1.2	Aug	-1.00	1.6
Deschutes River					
at Silver Creek	-0.63	1.7	Mar	-0.47	4.0
at Spurgeon Creek	-0.87	1.5	Feb-Mar	-0.69	5.9
at Tumwater Falls	-0.95	1.1	Feb	-0.74	3.7
McAllister Valley					
at Medicine Creek	-0.68	1.1	Aug	-0.68	1.1
Woodland Creek					
at Hicks Lake outfall	-0.07	10.5	Mar-Oct	-0.07	10.5
at Henderson Inlet	-0.08	6.2	Sep-Oct	-0.08	3.2

Note: Negative rates indicate monthly groundwater discharge depletion versus the baseline case. % - percentage of baseline discharge depleted. *month* – month in which highest loss would occur. Summer = Jun-Sep inclusive.

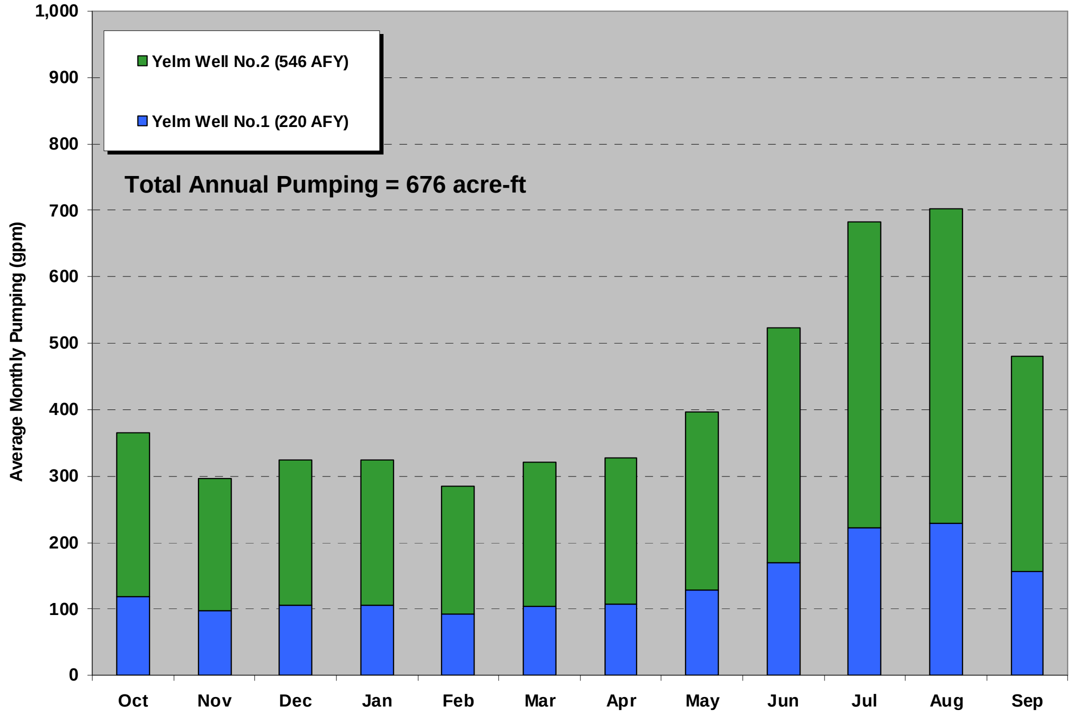
4.4.2 Groundwater Level Changes

Figures 4-20 through 4-23 show the model-predicted monthly groundwater levels in four key wells for the New Baseline case, Case A and Case D simulations.

- Downtown Well 1 – one of Yelm's two existing downtown wells, completed in the Vashon Outwash aquifer (Figure 4-20).
- SW Yelm Well 1 – one of the five planned wells from the new wellfield (Figure 4-6), to be completed in the upper part of the deep, undifferentiated aquifer (Figure 4-21).
- City of Rainier Well – one of several municipal wells located close to the downtown area of Rainier, completed in the Pre-Vashon Gravel aquifer (Figure 4-22).
- Schoepfer Well – a private well, located north of the planned wellfield area, completed in the deep, undifferentiated aquifer (Figure 4-23).

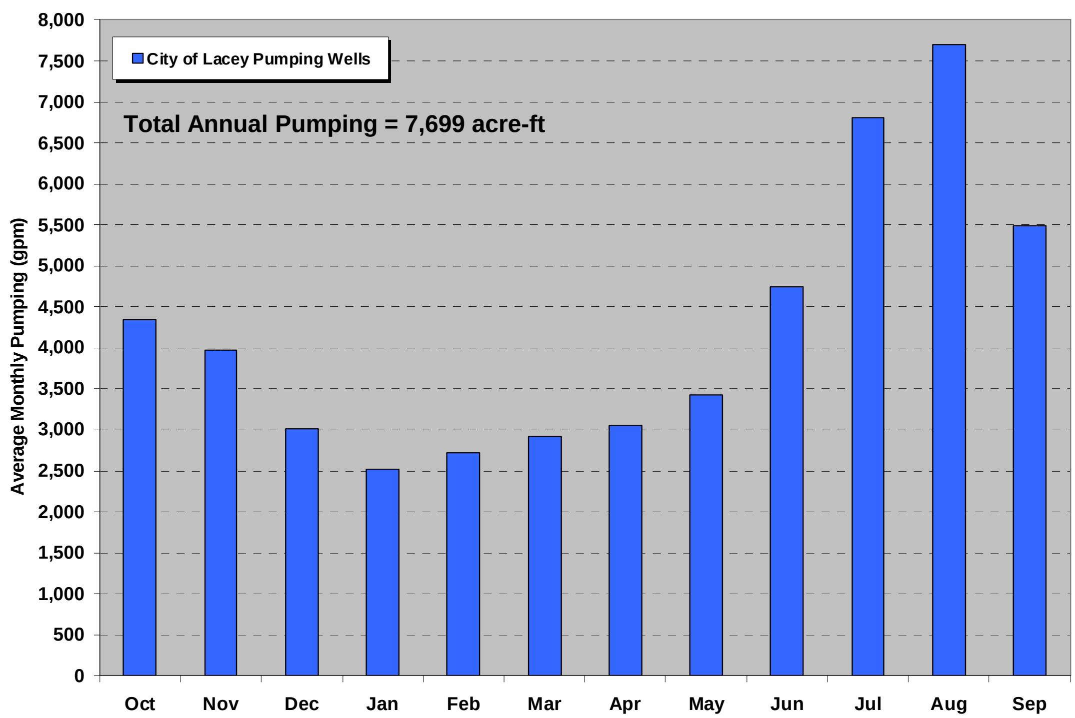
The future groundwater level in Yelm's downtown Well 1 will increase by up to 2 feet in response to Case A, and decrease by up to 1 foot from Case D. Neither case is expected to cause local groundwater problems in terms of flooding (for Case A) or excessively low levels in other wells (for Case D).

The predicted changes in water levels in the deep aquifer in the planned wellfield area range between 10 and 23 feet for Case A, and from 6 to 13 feet for Case D. This long-term drawdown is expected to be manageable in terms of well construction and operation. The predicted water level changes in the City of Rainier well range between 1.7 and 2.6 feet for Case A, and between 1.3 and 1.9 feet for Case D. The predicted water-level changes in the Schoepfer Well range between 0.8 and 1.2 feet for Case A, and between 0.7 and 1.0 feet for Case D. These long-term drawdowns are not expected to significantly impact the operation of either well.



Golder Associates

TITLE	**Simulated Pumping for City of Yelm Wells – New Baseline Case**		
City of Yelm – Future SW Yelm Wellfield Simulations	DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
	CHECKED PAB	SCALE	DWG No.
	REVIEWED JS	FILE No.	FIGURE No. 4-1



Golder Associates

TITLE	**Simulated Pumping for City of Lacey Wells – New Baseline Case**		
City of Yelm – Future SW Yelm Wellfield Simulations	DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
	CHECKED PAB	SCALE	DWG No.
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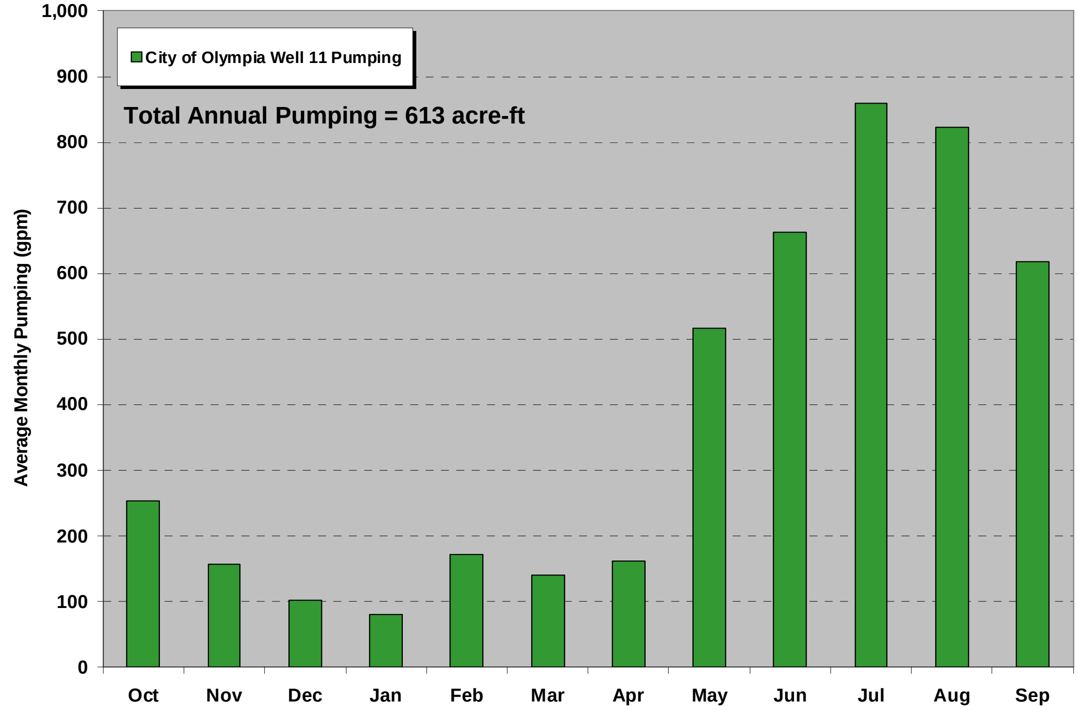
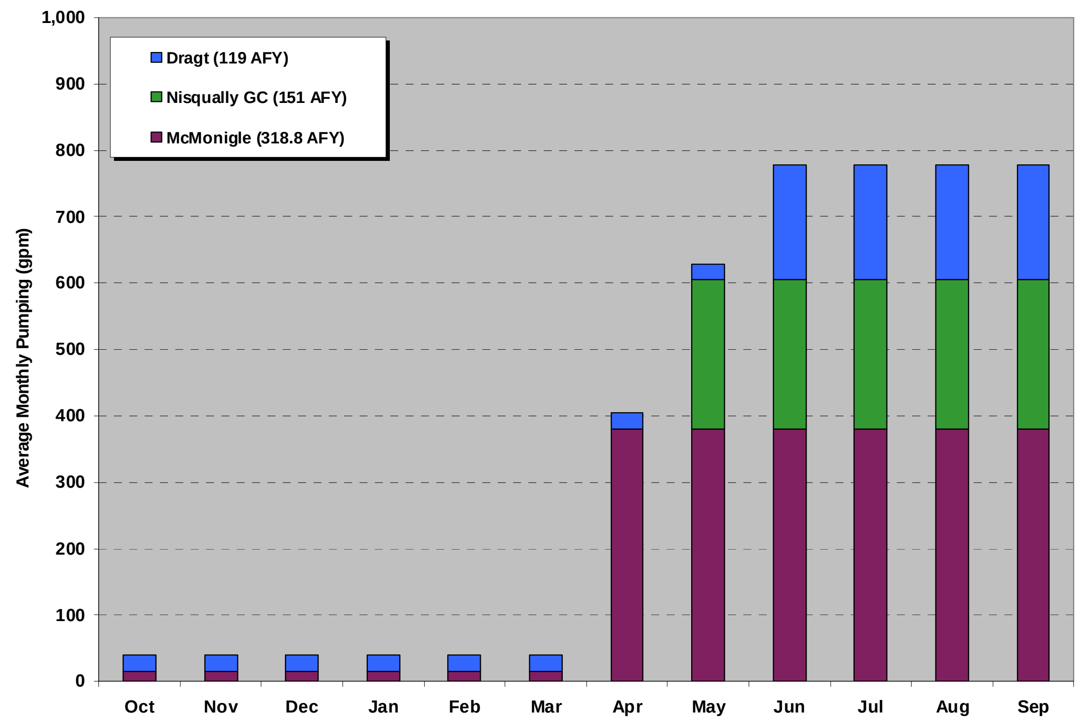


Golder Associates

TITLE	Simulated Pumping for City of Olympia Well 11 – New Baseline Case				
DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.		FIGURE No.	4-3

City of Yelm – Future SW Yelm Wellfield Simulations



Golder Associates

TITLE	Simulated Pumping for Other Yelm-area Wells – New Baseline case				
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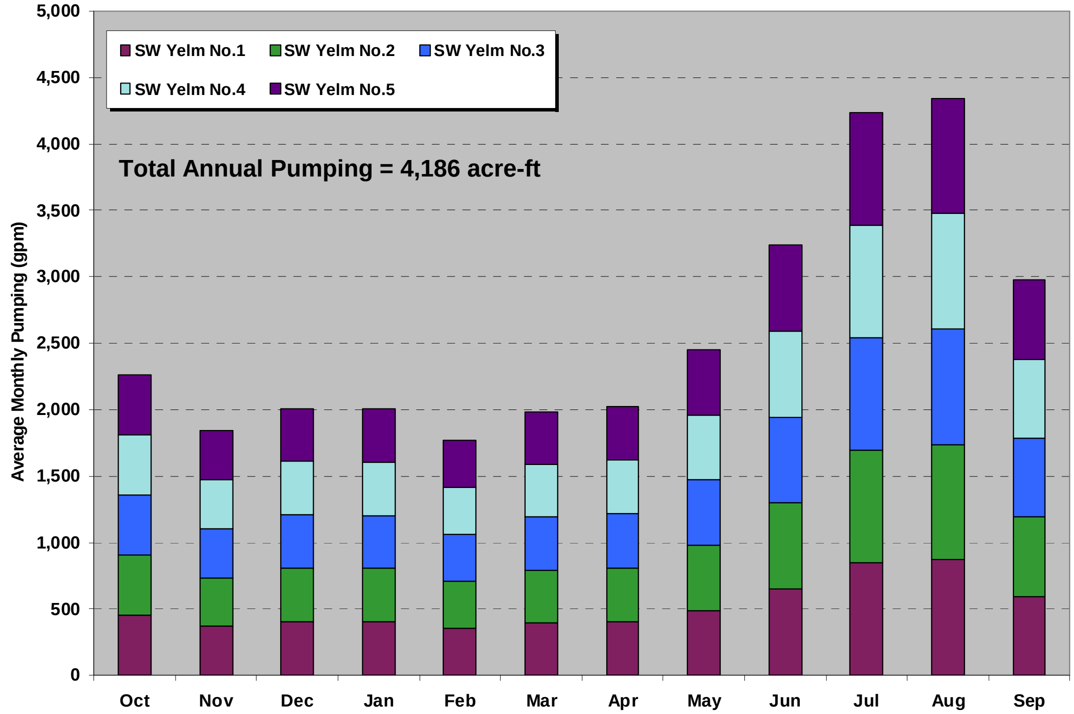
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No. Sims_figs_port.ppt		FIGURE No.	4-4

City of Yelm – Future SW Yelm Wellfield Simulations

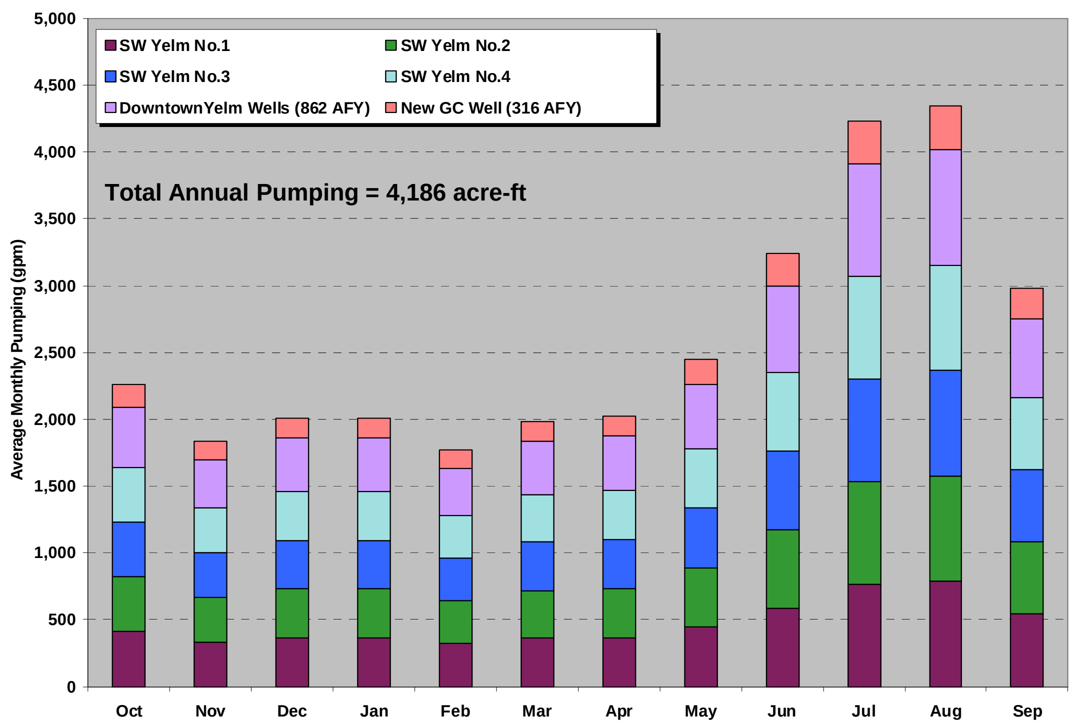


Golder Associates

TITLE **Simulated Pumping for City of Yelm Wells – Case A**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.		FIGURE No.	4-5



Golder Associates

TITLE **Simulated Pumping for City of Yelm Wells – Case D**

City of Yelm – Future SW Yelm Wellfield Simulations

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CHECKED	PAB	SCALE		DWG No.	
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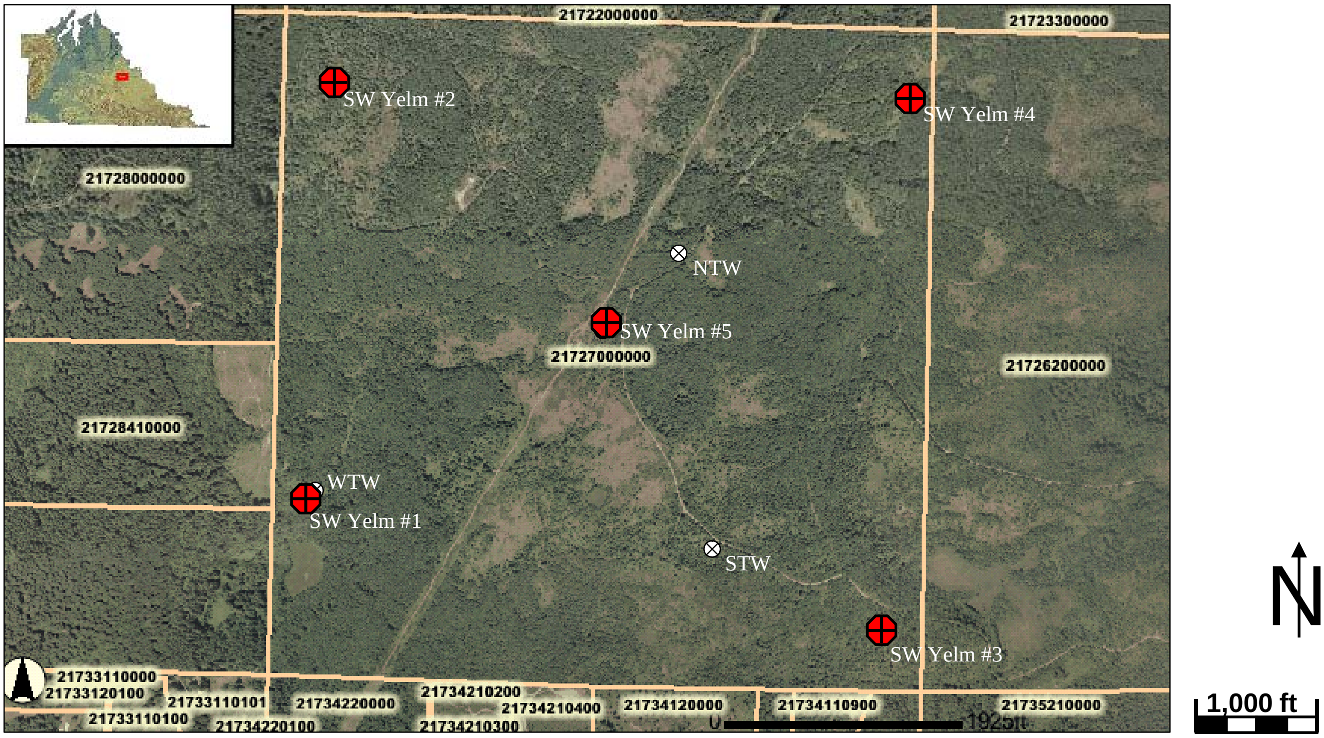


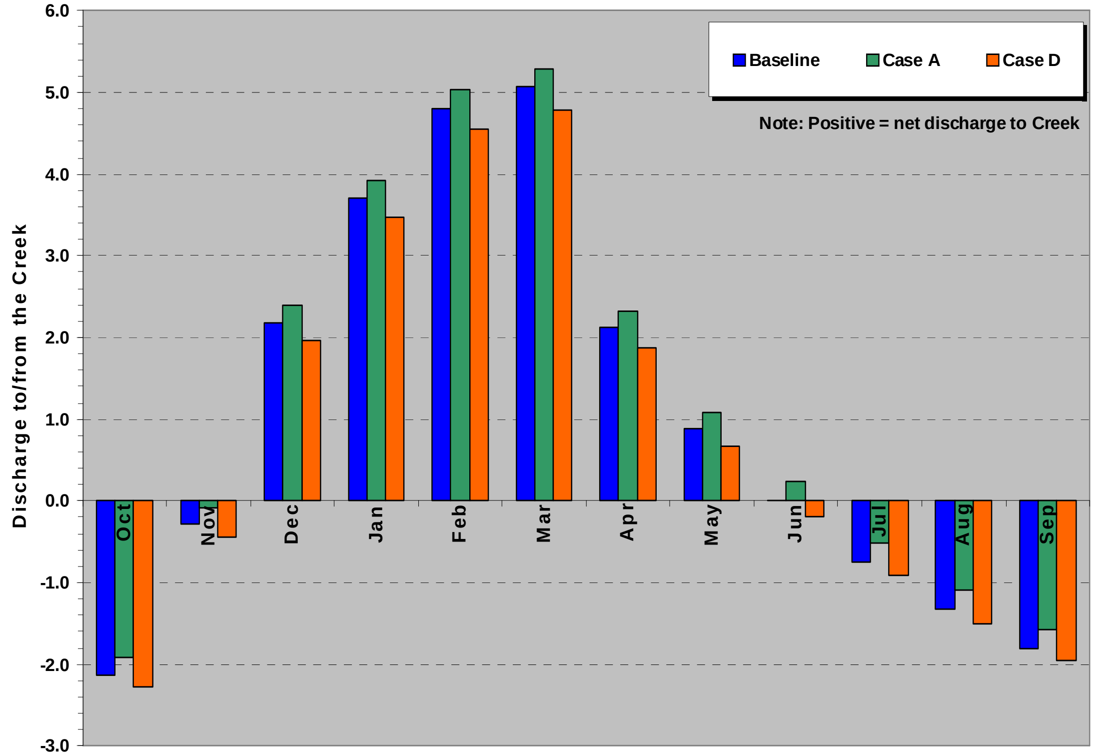
Golder Associates

TITLE

Possible SW Yelm Wellfield Layout - Case A

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.		FIGURE No.	4-7

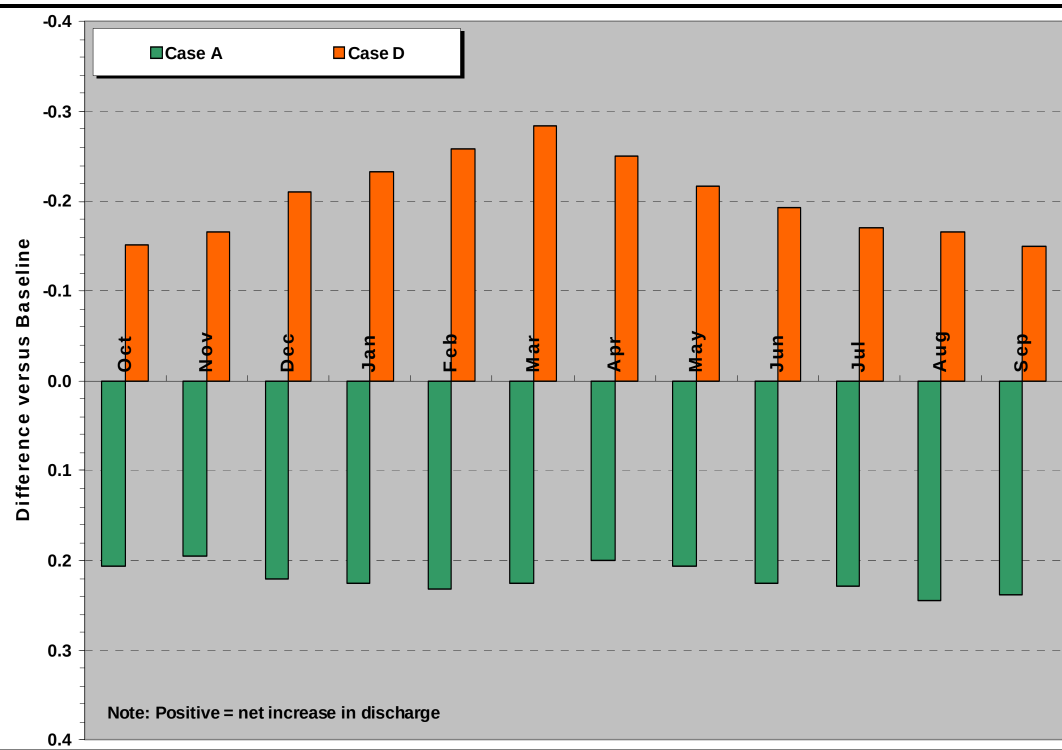


Golder Associates

TITLE **Predicted Groundwater Discharge to Yelm Creek – New Baseline, Case A and Case D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.	Sims_figs_port.ppt	FIGURE No.	4-8



Golder Associates

TITLE **Predicted Changes in Discharge to Yelm Creek versus New Baseline – Cases A and D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
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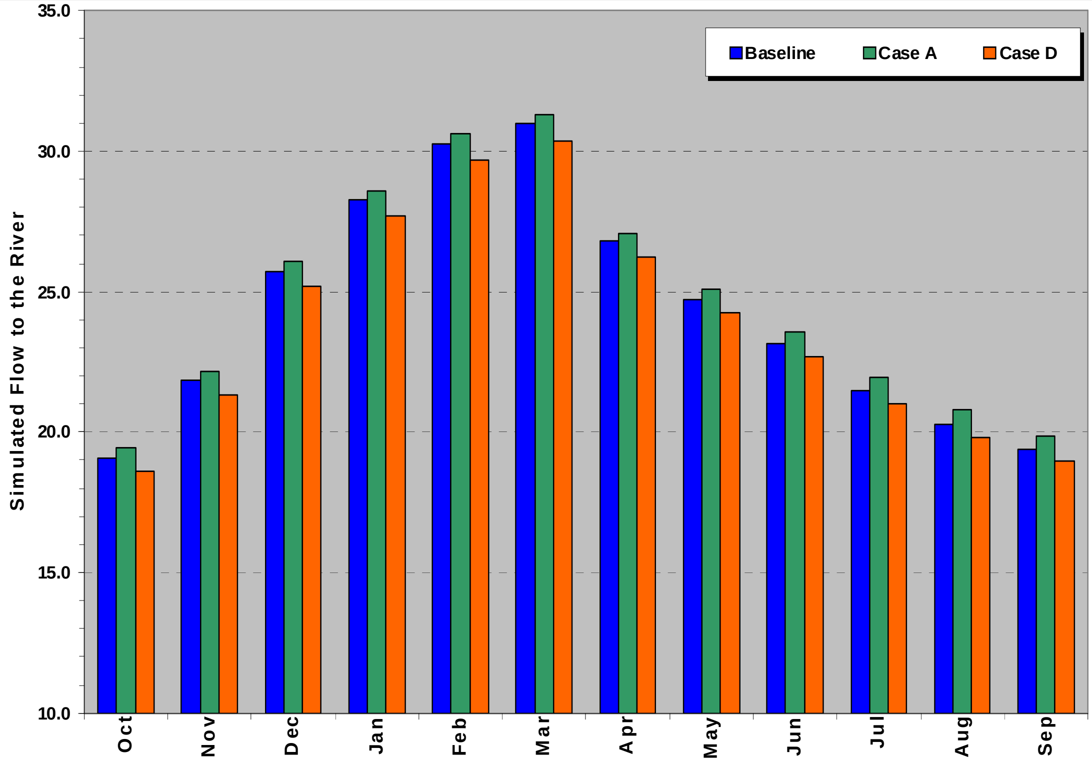

Golder Associates

TITLE **Predicted Groundwater Discharge to U. Nisqually River above Thompson Creek - New Baseline, Case A and Case D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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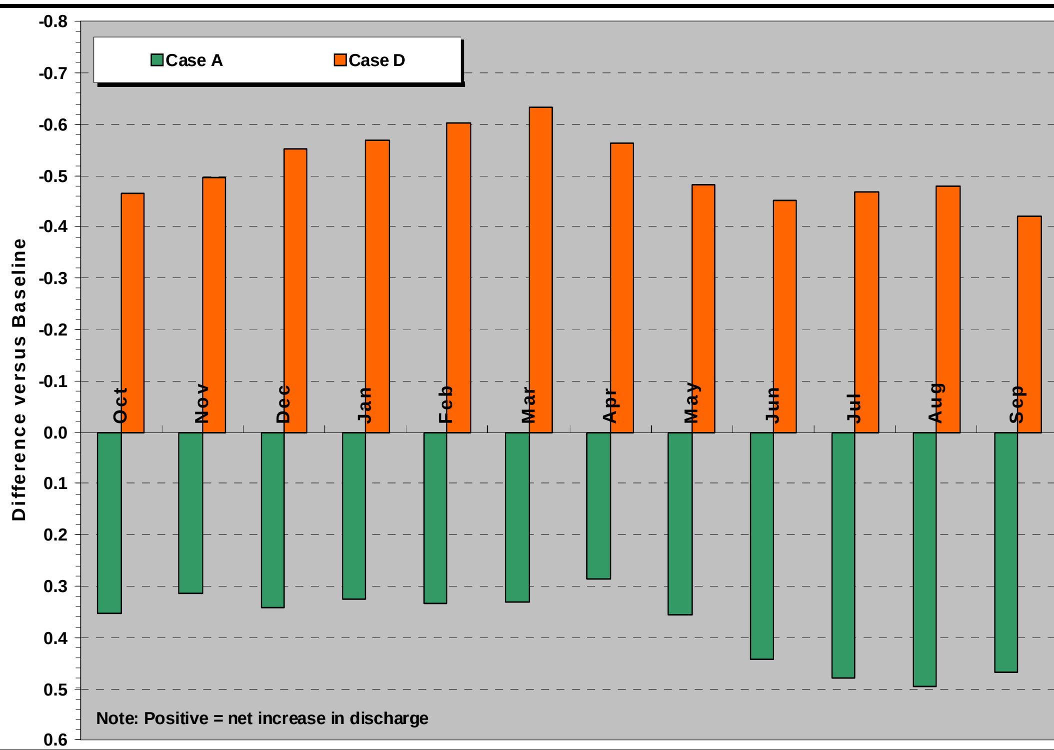

Golder Associates

TITLE **Predicted Changes in Discharge to U. Nisqually River above Thompson Creek versus New Baseline – Cases A and D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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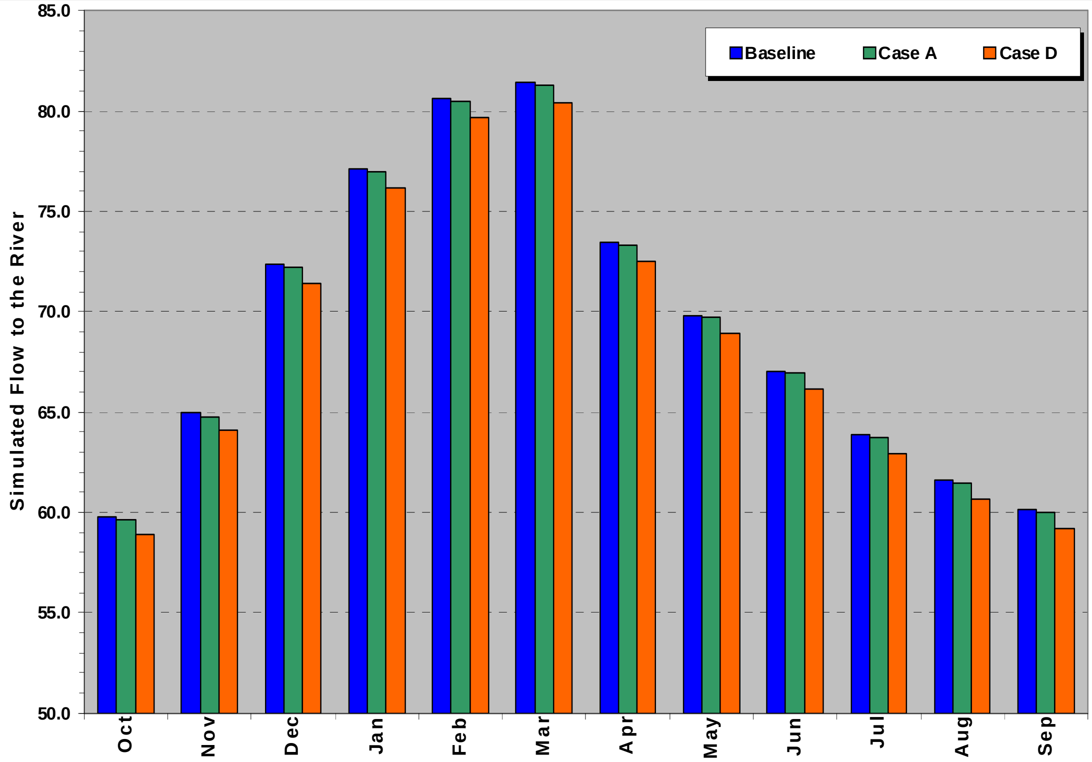

Golder Associates	TITLE **Predicted Groundwater Discharge to Nisqually River above RM 4.3 – New Baseline, Case A and Case D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
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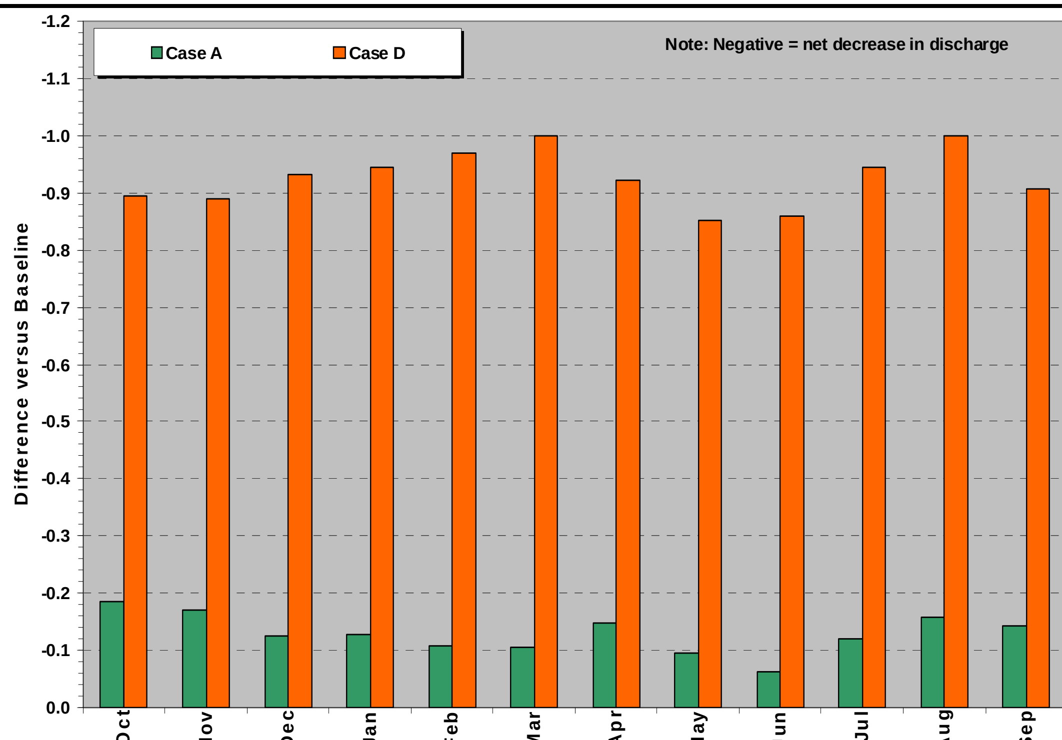

Golder Associates	TITLE **Predicted Changes in Discharge to Nisqually River above RM 4.3 versus New Baseline – Cases A and D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN SDT	DATE 1/29/08	PROJECT No. 043-1328.500
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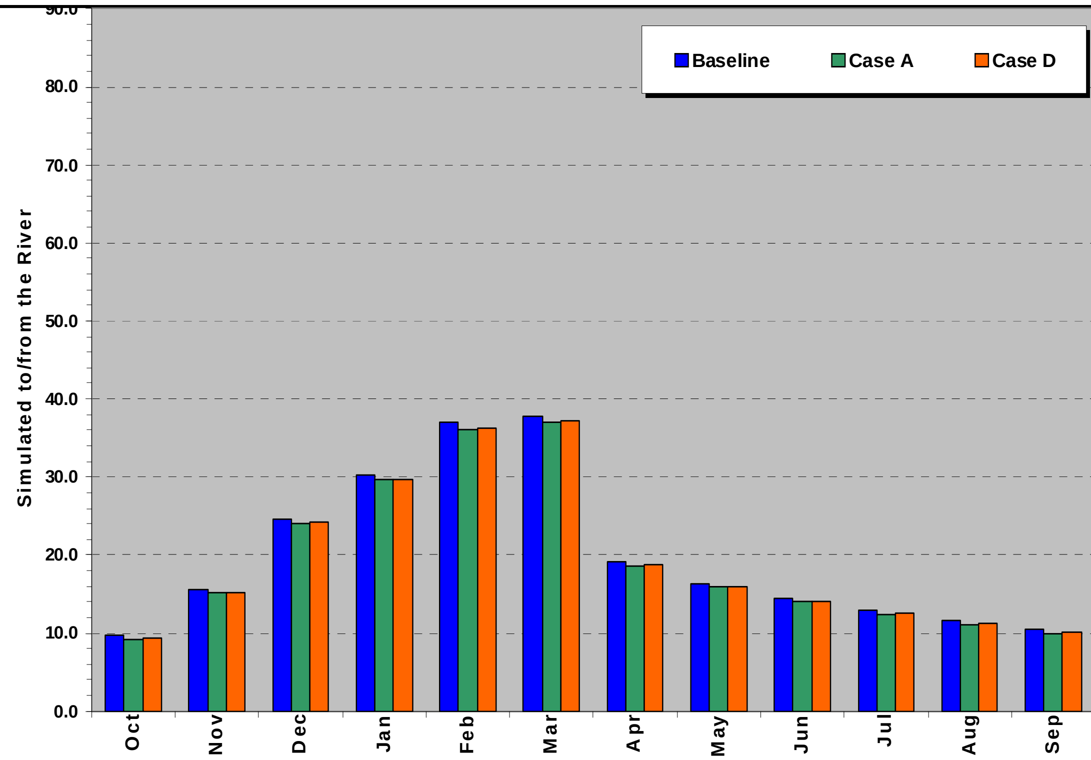

Golder Associates	TITLE **Predicted Groundwater Discharge to Deschutes River at Silver Creek – New Baseline, Case A and Case D**

City of Yelm – Future SW Yelm Wellfield Simulations						
	DRAWN	SDT	DATE 1/29/08		PROJECT No.	043-1328.500
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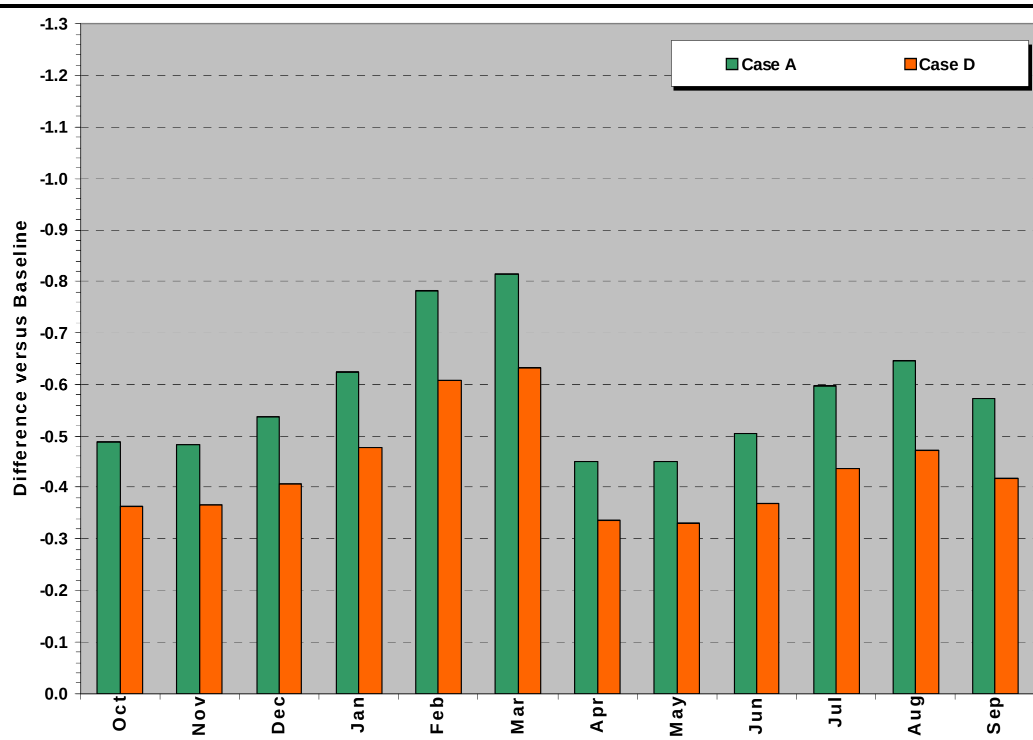

Golder Associates	TITLE **Predicted Changes in Discharge to Deschutes River at Silver Creek versus New Baseline – Cases A and D**

City of Yelm – Future SW Yelm Wellfield Simulations						
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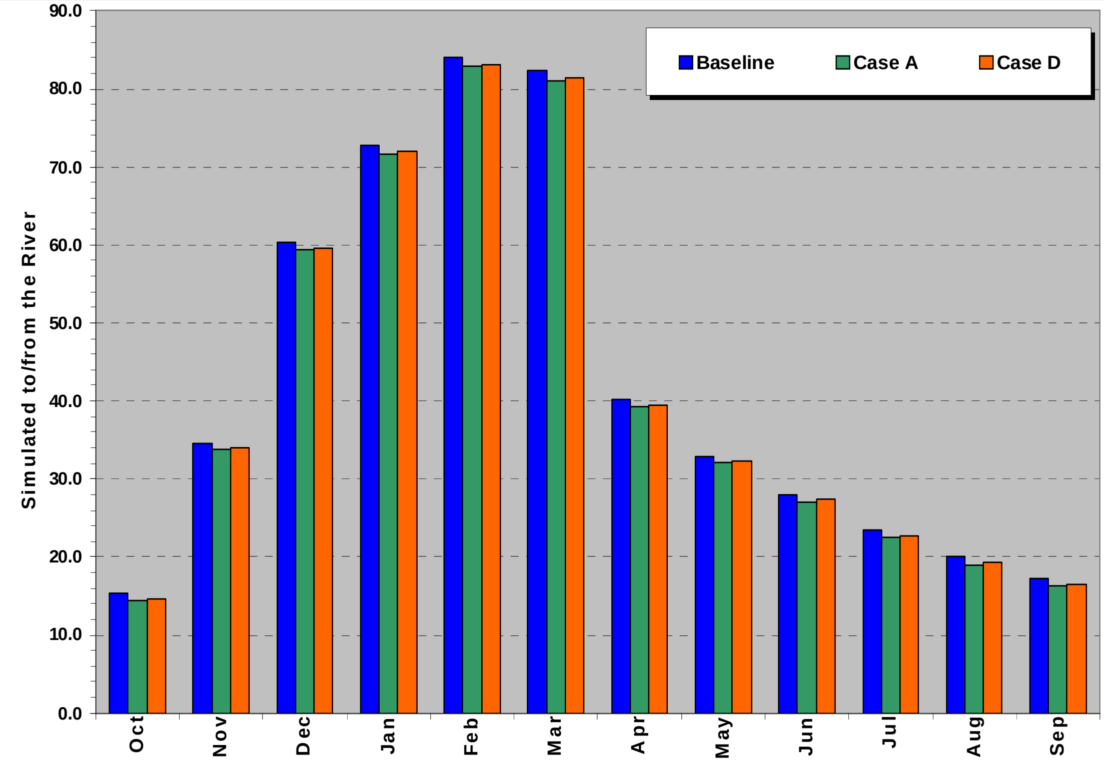

Golder Associates

TITLE
Predicted Groundwater Discharge to Deschutes River above Tumwater – New Baseline, Case A and Case D

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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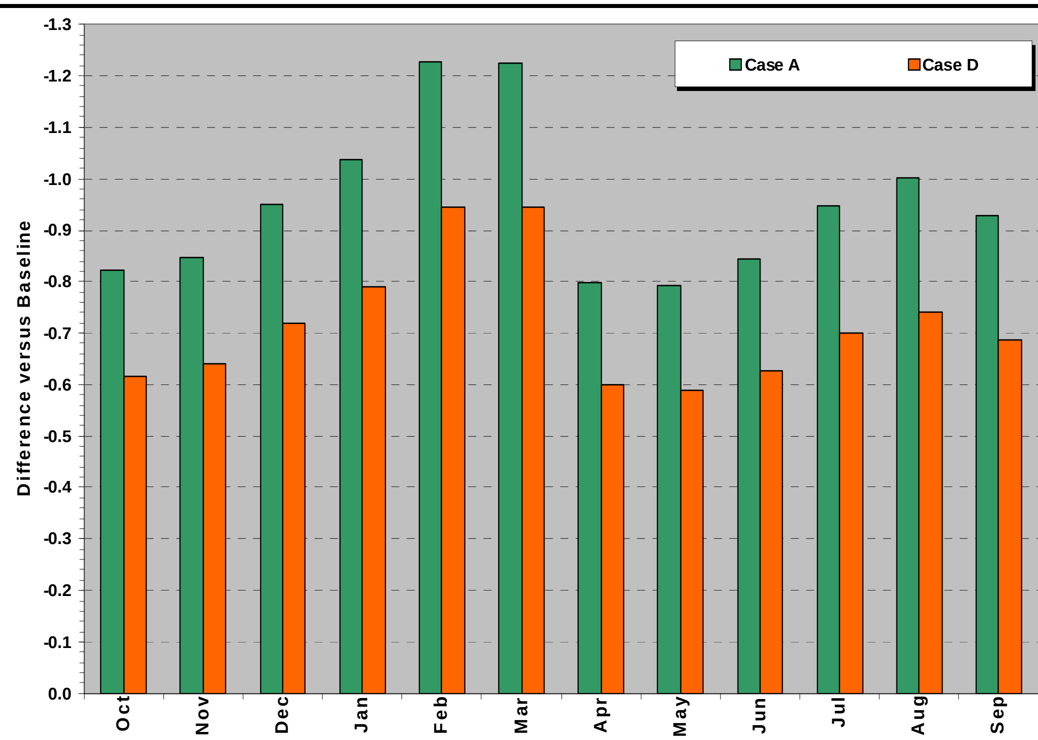

Golder Associates

TITLE
Predicted Changes in Discharge to Deschutes River above Tumwater versus New Baseline – Cases A and D

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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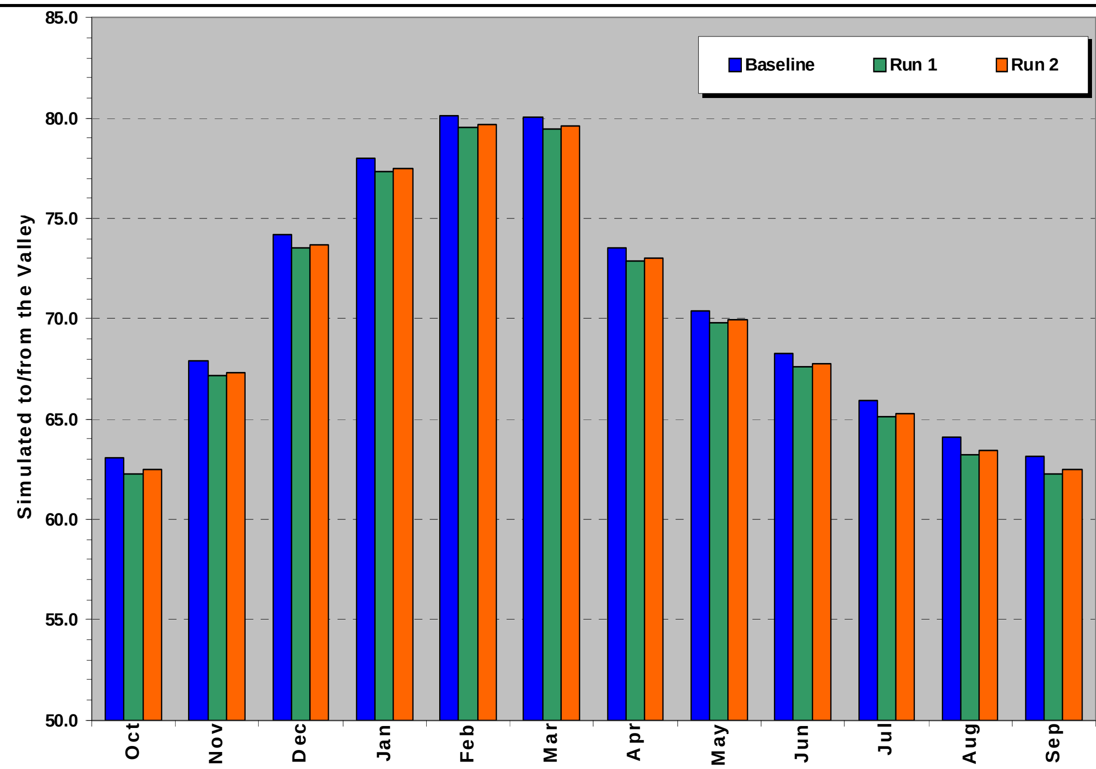

Golder Associates

TITLE **Predicted Groundwater Discharge to McAllister Creek – New Baseline, Case A and Case D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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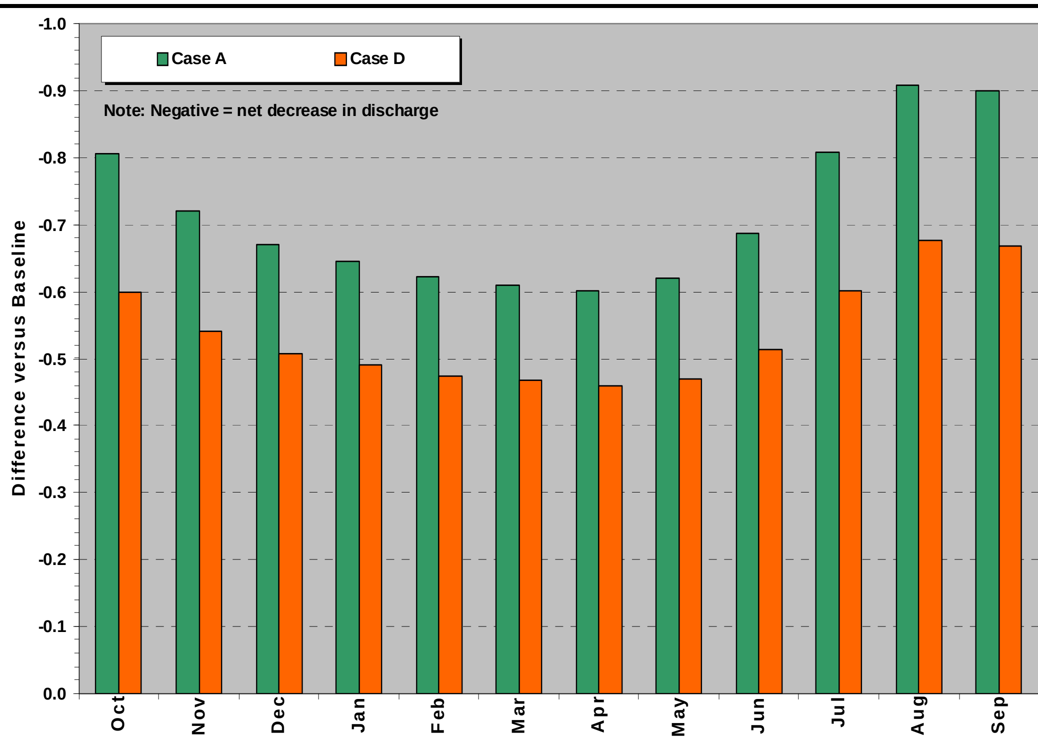

Golder Associates

TITLE **Predicted Changes in Discharge to McAllister Creek versus New Baseline – Cases A and D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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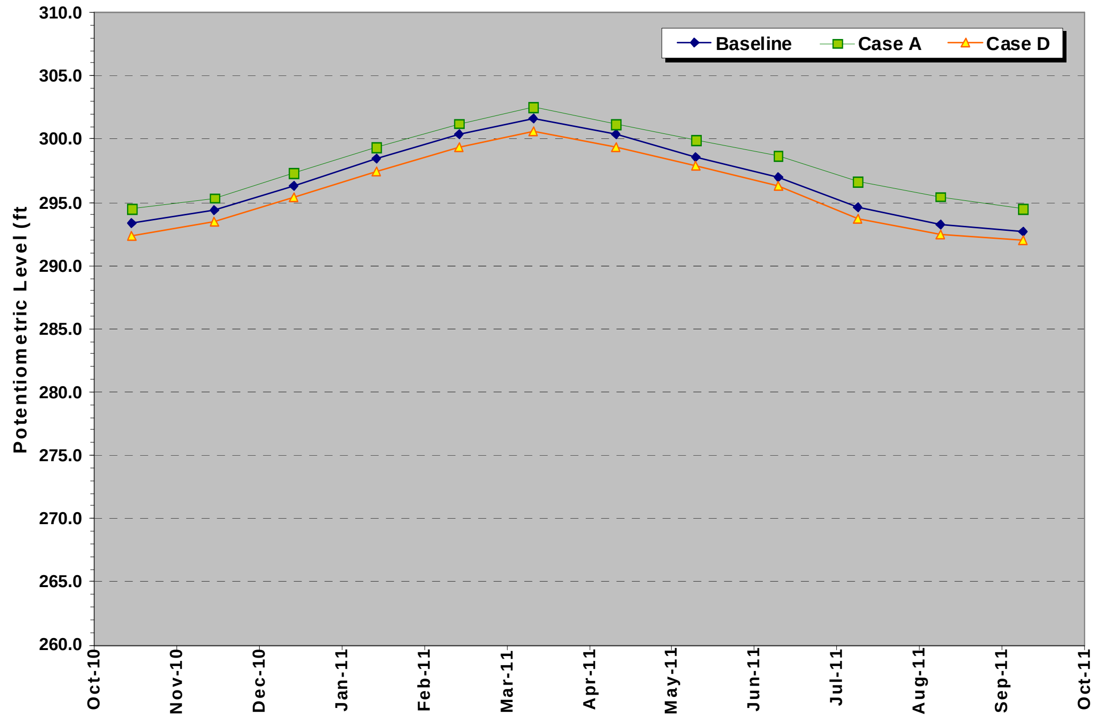

Golder Associates	TITLE **Predicted Groundwater Levels in Yelm No. 1 – New Baseline, Case A and Case D**				
City of Yelm – Future SW Yelm Wellfield Simulations	DRAWN SDT	DATE 1/29/08		PROJECT No. 043-1328.500	
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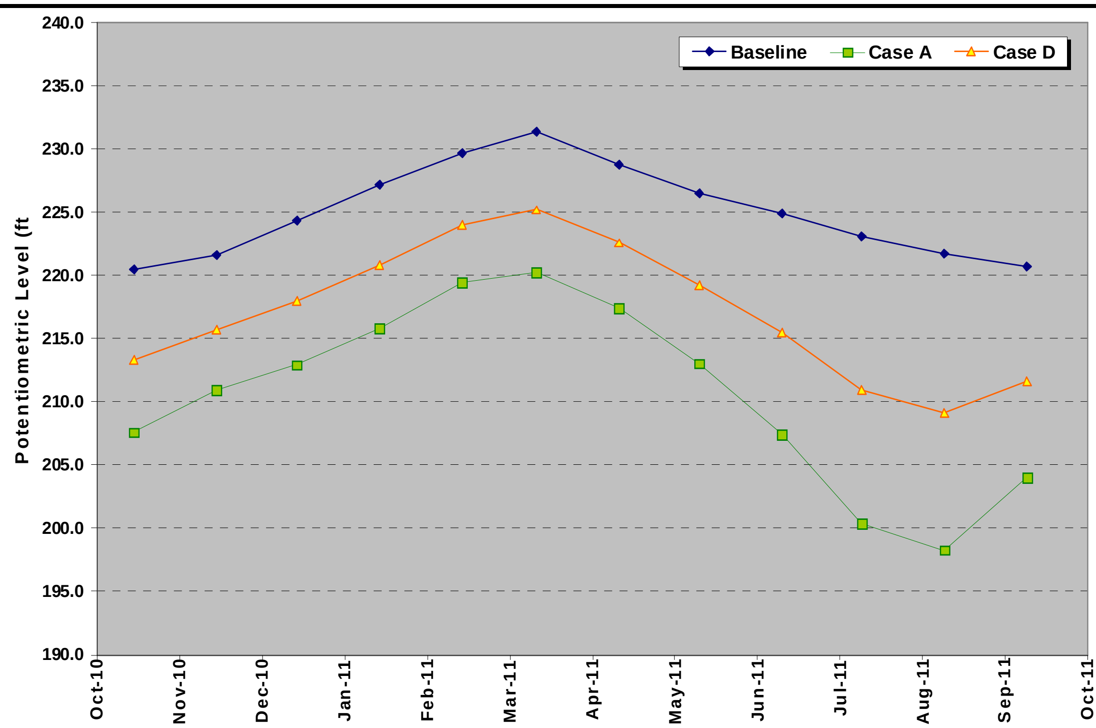

Golder Associates	TITLE **Predicted Groundwater Levels in SW Yelm Well No.1 – New Baseline, Case A and Case D**				
City of Yelm – Future SW Yelm Wellfield Simulations	DRAWN SDT	DATE 1/29/08		PROJECT No. 043-1328.500	
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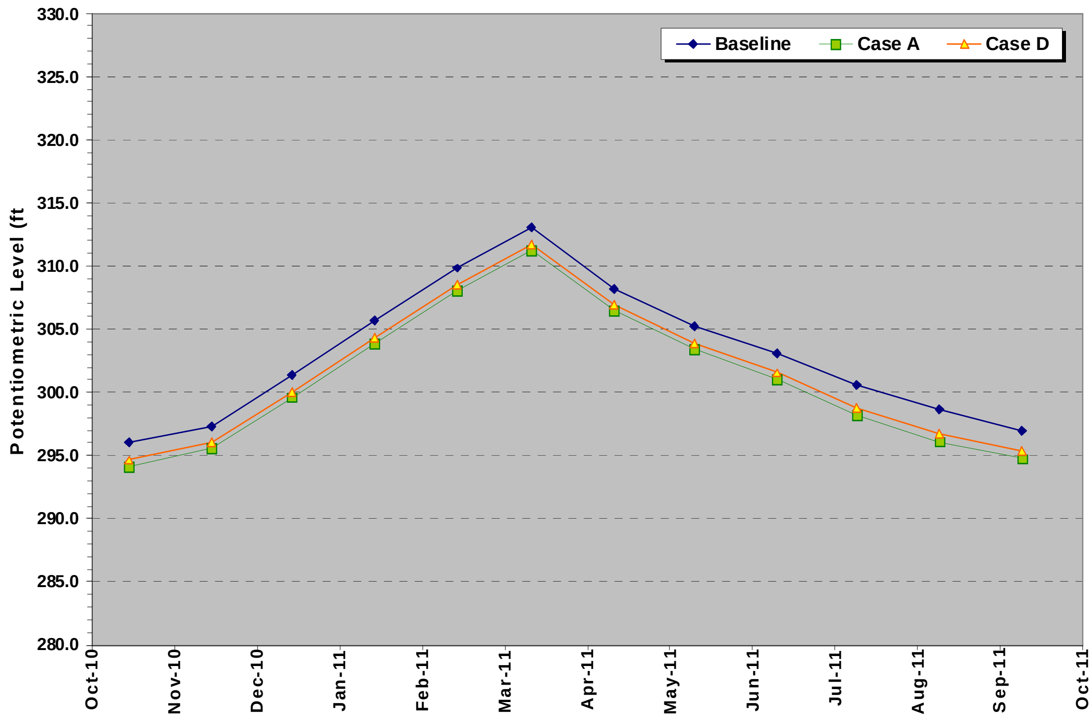

Golder Associates

TITLE **Predicted Groundwater Levels in City of Rainier Well – New Baseline, Case A and Case D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
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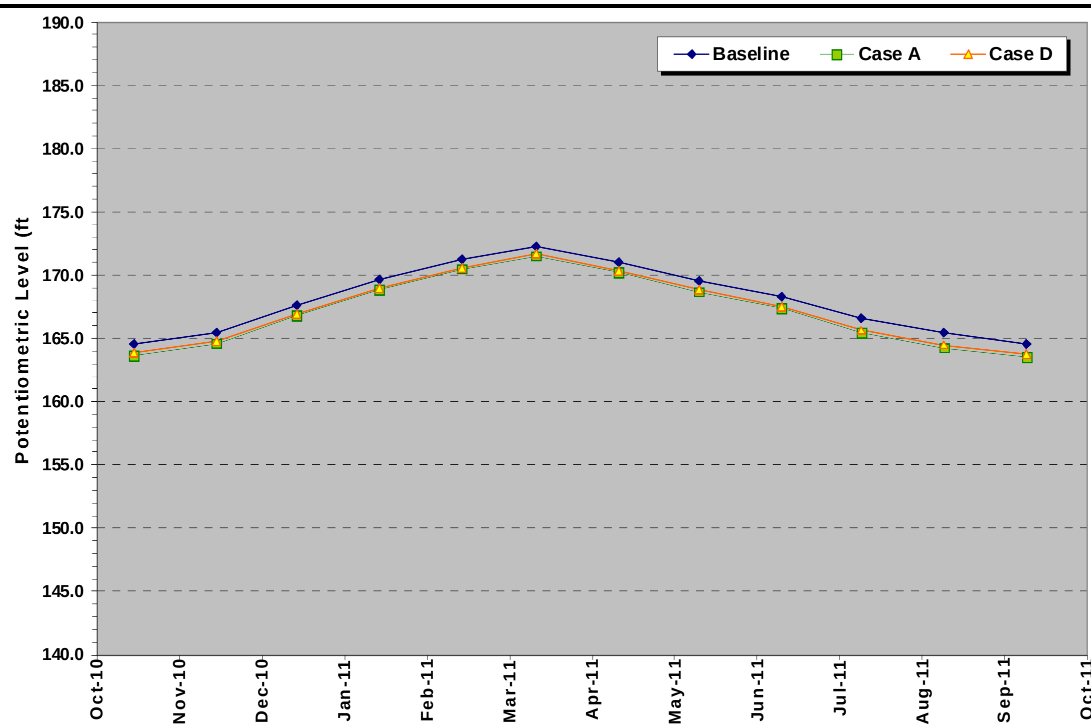
REVIEWED	JS	FILE No.	Sims_figs_port.ppt	FIGURE No.	4-22



Golder Associates

TITLE **Predicted Groundwater Levels in Schoepfer Well – New Baseline, Case A and Case D**

City of Yelm – Future SW Yelm Wellfield Simulations

DRAWN	SDT	DATE	1/29/08	PROJECT No.	043-1328.500
CHECKED	PAB	SCALE		DWG No.	
REVIEWED	JS	FILE No.	Sims_figs_port.ppt	FIGURE No.	4-23

5.0 CONCLUSIONS AND DISCUSSION

Based on the numerical modeling presented in the previous sections, Golder makes the following concluding statements.

Several revisions were made to the McAllister Groundwater Model to improve the representation of important hydrologic features. These included addition of a discrete boundary reach for the middle part of the Deschutes River, the tributary Silver Creek and associated spring area, a revision of pumping rates for wells in the City of Olympia's East Olympia Wellfield and the private McMonigle wells (in the Yelm area), and the transmissivity of the upper portion of the undifferentiated (TQu) aquifer in the Olympia area. Overall, these revisions improved the level of confidence in using the model to predict hydrologic impacts.

The revised version of the model was then used to simulate two future wellfield scenarios for the City of Yelm. These cases involved the following:

- Case A - Using the planned SW Yelm Wellfield to supply the full demand of 4,186 afy while relinquishing pumping at Yelm's downtown wells, the Dragt wells and the Nisqually Golf Course wells.

- Case D - Using the planned SW Yelm Wellfield, the existing downtown wells, and the transferred Dragt and Nisqually Golf Course water rights to meet the 4,186 afy demand.

At this stage, Case D is being considered by the City as an interim option, and Case A the preferred long-term condition.

For Case A:

- The groundwater discharge directly to both Yelm Creek and the upper reach of the Nisqually River will <u>increase</u> throughout the year, with maximum increases predicted in the summer months of 0.24 cfs and 0.25 cfs, respectively.
- Although the increase in deep aquifer pumping will decrease the groundwater discharge to the middle and lower reaches of the Nisqually River (up to 0.21 cfs and 0.37 cfs, respectively), the net impact on groundwater flow to the Nisqually River upstream from RM 4.3 will be an overall decrease of between 0.06 cfs (in June) and 0.19 cfs (in October). The minimum in stream flow rule at this point is between 600 (in September) and 900 cfs (Ecology, 1988).
- The increase in deep pumping associated with the new wellfield will decrease groundwater discharge to the upper McAllister Valley (between 0.6 and 0.91 cfs) and to the Deschutes River above Tumwater (between 0.79 and 1.23 cfs). Most of the flow reduction to the Deschutes River will occur upstream of Silver Creek.

- The reduced shallow pumping under this scenario will result in higher (up to 2 feet) groundwater levels in the Qga aquifer in the downtown area of Yelm. This rise is not expected to cause local groundwater problems in terms of flooding. The increase in deep aquifer pumping at the new wellfield will lower groundwater levels beneath the Highlands area up to 23 feet. This long-term drawdown is expected to be manageable in terms of well construction and operation.

For Case D:

- The groundwater discharge directly to Yelm Creek and the upper reach of the Nisqually River will decrease up to 0.28 cfs and 0.35 cfs, respectively. However, the summertime depletions to these reaches will be less than the annual maximum (0.19 cfs and 0.31 cfs).
- The increase in deep aquifer pumping will also decrease the groundwater discharge to the middle and lower reaches of the Nisqually River (up to 0.18 and 0.28 cfs, respectively). The total impact on groundwater flow to the Nisqually River above RM 4.3 will be between 0.85 cfs (in May) and 1.0 cfs (in March), which is greater than the impacts predicted for Case A.
- The increase in deep aquifer pumping will decrease groundwater discharge to the upper McAllister Valley (between 0.46 and 0.68 cfs) and to the Deschutes River above Tumwater (between 0.59 and 0.95 cfs). The peak summertime impact to the Deschutes River will be 0.74 cfs. The predicted depletions to both the McAllister Valley and Deschutes River under Case D are lower than those predicted for Case A.
- Increased pumping for Case D will cause shallow aquifer levels in the Yelm area to fall up to 1 foot, and deep aquifer levels in the Highlands area to fall up to 13 feet. Neither change is expected to cause local groundwater management problems.

Variations of both Cases A and D were simulated previously using an earlier version of the model (Golder, 2007a). Because multiple changes in pumping under the Baseline case and the two scenarios were made, it is difficult to directly compare the previous and current results. However, predicted hydrologic impacts for both future wellfield scenarios were generally similar. These results are summarized in Table 5-1 below.

The most significant difference between the two result sets concerns the Deschutes River. The apparent increase in depletions at the river for both Cases A and D results from the addition of Spurgeon Creek and Silver Spring/Creek in the most recent version. However, the negative impacts to the Nisqually River and McAllister Valley are slightly diminished using the updated version of the model.

TABLE 5-1

Comparison between Original and Revised Model Predictions – Cumulative Impacts

Hydrologic Area/Feature	Original Model Highest Annual Discharge Change		Revised Model Highest Annual Discharge Change	
	cfs	*month(s)*	*cfs*	*month(s)*
CASE A				
Nisqually River				
at Thompson Creek	+0.46	Jan-Feb	+0.50	Aug
at Nisqually Indian Resvn.	+0.30	Feb	+0.22	Sep
at RM 4.3	-0.33	Oct	-0.19	Oct
Deschutes River				
at Silver Creek	-0.92[(1)]	Apr	-0.82	Mar
at Spurgeon Creek	NA	NA	-1.12	Feb-Mar
at Tumwater Falls	-1.00[(2)]	Apr	-1.23	Feb-Mar
McAllister Valley				
at Medicine Creek[(3)]	-0.95	Aug	-0.91	Aug
CASE D				
Nisqually River				
at Thompson Creek	-0.52	Mar	-0.63	Mar
at Nisqually Indian Resvn.	-0.71	Mar	-0.81	Mar
at RM 4.3	-0.94	Aug	-1.00	Aug
Deschutes River				
at Silver Creek	-0.64[(1)]	Feb	-0.63	Mar
at Spurgeon Creek	NA	NA	-0.87	Feb-Mar
at Tumwater Falls	-0.71[(2)]	Feb	-0.95	Feb
McAllister Valley				
at Medicine Creek	-0.74	Aug	-0.68	Aug

Note: Negative rates indicate groundwater discharge depletion versus the baseline case. *month* – month in which highest loss would occur. (1)- former upper Deschutes reach only; (2) – former upper and lower Deschutes reaches only; (3) – includes all upper-valley springs, wetlands, side-valley springs and McAllister Creek.

Even with the additional revisions and improvements, the McAllister Numerical Groundwater Model remains relatively conservative in terms of predicting hydrologic impacts from changes in groundwater pumping. That is, the model is constructed in a manner that would tend toward over-prediction of groundwater level changes and the subsequent impacts to surface water. The original intent of the model was to predict these effects so as to be protective of both water rights holders in the western Nisqually and eastern Deschutes watersheds, and the habitat which rely on the surface waters of the region. In particular, the boundary conditions that were assigned beneath the Nisqually and Deschutes rivers prevent groundwater flowing into the model domain in the deep, regionally-extensive TQu aquifer. These rivers serve as hydraulic divides in the shallowest portion of the aquifer system, but groundwater would be able to enter the model area in deeper layers in response to increased deep pumping. Consequently, the model over-predicts the extent and magnitude of the hydraulic effects of pumping in the deeper portions of the aquifer system. Therefore, the predicted results should be considered conservative, and viewed cautiously as "worst case" results.

As with the previous predictive simulations, several depletions fall below the sensitivity thresholds defined for the model. These thresholds are as follows:

- Minimum change in direct discharge compared to the Baseline case of 0.01 cfs.
- Minimum relative change in discharge of 1 percent of the Baseline case rate.

Consequently, results at or below these thresholds should not be viewed as significant or measurable. If depletions of this magnitude become problems in the development of the future wellfield, serious consideration should be given to revising the model boundary conditions to more closely reflect actual subsurface hydraulics rather than accept the results as real impacts worthy of consideration for mitigation.

The two scenarios illustrate the choices and tradeoffs associated with hydrologic impacts to meet the 2038 demand forecast. If Case D is selected as an interim option (with up to as many as four new wellfield wells), negative impacts are predicted to the upper Nisqually River. However, when Case A becomes operational (with all 4,186 afy from a five-well wellfield), a positive impact is predicted for the same reach of the Nisqually River due to cessation of more than 1,000 afy of shallow pumping in downtown Yelm. Although Case D would also result in negative impacts to the more remote features (the lower Nisqually and Deschutes Rivers, and McAllister Valley), the magnitude of the impacts would be lower than under Case A.

Yelm is developing opportunities to use existing water rights to transfer, retire and shift production patterns in time to reduce the depletions to surface water features during the summer months when flows are most critical. Because of the shift from irrigation to municipal use, many of the maximum predicted depletions occur in the winter or spring months, presumably when in-stream flows are being met, and resulting in benefits to summer flows in the Yelm area.

Despite its conservative nature, Golder believes that the McAllister Numerical Groundwater Model is a useful predictive tool, and that these results will aid the City of Yelm in preparing an overall water supply development and permitting strategy that best serves the needs of Yelm, the environment and the watershed as a whole.

REFERENCES

CDM, 2002a. Model Construction and Steady-state Calibration - McAllister Wellfield Numerical Model. Prepared for the City of Olympia Public Works Dept. April.

CDM, 2002b. Final Report – McAllister Wellfield Numerical Model. Prepared for the City of Olympia Public Works Dept. July.

Drost, B.W., D.M. Ely, and W.E. Lum II. 1999. Conceptual Model and Numerical Simulation of the Ground-Water Flow System in the Unconsolidated Sediments of Thurston County, Washington. USGS Water-Resources Investigation Report 99-4165.

Golder Associates, Inc. (Golder). 2006. Groundwater Modeling of Water Right Applications and Transfers. Prepared for the City of Lacey. February 16, 2006.

Golder, 2007a. Report on Groundwater Modeling of New Water Right and Transfer Applications, City of Yelm, Washington. Prepared for the City of Yelm. March 9, 2007.

Golder, 2007b. East Olympia Wellhead Protection Areas - Existing Data Review and Numerical Model Evaluation. Prepared for the City of Olympia. September 6, 2007.

HDR/SSPA, 2006. Technical Memorandum - McAllister Wellfield Hydrologic Impacts Analysis. Prepared for the City of Olympia, Dept. of Public Works. April 3, 2006.

HydroGeoLogic. 1996. MODFLOW-SURFACT software. Version 2.2.

Konovsky, J. 2007a. Personal communication, June 27, 2007.

Konovsky, J. 2007b. Personal communication, November 1, 2007.

Pacific Groundwater Group (PGG), 2007. Technical Memorandum – McMonigle Wells. Prepared for Rainier General Development. November 7, 2007.

Sinclair, K.A, and D.B. Bilhimer, 2007. Assessment of Surface Water/Groundwater Interactions and Associated Nutrient Fluxes in the Deschutes River and Percival Creek Watersheds, Thurston County. Watershed Environmental Program. Publication No. 07-03-002. January 2007.

Washington State Department of Ecology (Ecology). 1988. In-stream Resources Protection Program – Nisqually River Basin, Water Resources Protection Inventory Area (WRIA 11). Chapter 173—511 WAC.