Golder Associates Inc.
2200 – 6th Avenue, Suite 600
Seattle, Washington 98121
Telephone: (206) 267 1166
Fax: (206) 267 1172

TECHNICAL MEMORANDUM

TO:	Shelly Badger – City of Yelm	**DATE:**	October 10, 2008
FR:	Stephen D. Thomas, R.G, C.HG.	**OUR REF:**	043-1328.300

RE: Future Demand/Supply Forecast and Groundwater Modeling for Mitigation Planning
CC: Phil Brown, P.G

1.0 OVERVIEW

This memorandum describes the work performed for the City of Yelm (the City) by Golder Associates Inc. (Golder) to assist with mitigation planning for the City's long-term water management program. The main components of the work consisted of:

(1) Establishing a phased approach to transferring and adding new groundwater wells to meet forecast future demand as provided by the City, and

(2) Applying a numerical groundwater flow model to estimate the hydrologic impacts of the future groundwater pumping on key surface water bodies and groundwater levels in the region (Figure 1).

The analysis involved defining specific phases of water system development to meet the planned demand. The methodology for the development of these phases is presented in Sections 2 and 3 below. Groundwater modeling was employed to simulate these phases and estimate monthly hydrologic impacts. Groundwater modeling is described in Section 4.

2.0 CAPACITY AND DEMAND FORECAST PLANNING

This section describes an approach and timeframe for water rights and system capacity development that is based on the demand forecast information provided to Golder by the City. This approach is based on the City's intention to phase the addition of new water rights and associated infrastructure and related mitigation over time. We recognize that it is possible that the actual mitigation approach and scale may vary from the pace of the steps that are designed to stay ahead of the demand forecast. However, we consider this approach to be a good basis for planning purposes, and one which can be adjusted as mitigation strategies present themselves.

2.1 Short-Term Demand/Water Rights Comparison

Table 1 shows the projected annual water demand (provided by Brown and Caldwell) through 2010, compared to the City's current water rights. This table shows that the City will see a shortfall in supply capacity by 2010 unless new water rights and the capacity to pump this water are added.

TABLE 1

Water Demands Compared with Current Water Rights

Year	Existing Water Rights	New water Rights	Total Water Rights	Annual Demand (Forecast)	Excess/Deficit Capacity
2007[4]	676	+155.66 +77 -112	796.66	730.5[1]	66.2
2008[5]	796.66	+155.61	952.27	819[2]	133.3
2009	952.27	0	952.27	843[3]	109.3
2010	952.27	0	952.27	1,085[3]	-132.7

Notes: All units are ac-ft/yr

(1) 2007 measured annual demand.

(2) Actual 2008 use is currently projected to be 755 AF. The 819 ac-ft/yr value referenced above is forecast based on conservative assumptions.

(3) Based on average annual demand projections prepared by Brown and Caldwell, July 2008.

(4) 2007: Added Dragt at 155.66 ac-ft/yr and Nisqually Golf Course at 77 ac-ft/yr (approved). Removed 112 ac-ft/yr due to Ecology 2007 recalculation of City of Yelm's historic water rights

(5) 2008: Added McMonigle at 155.61 ac-ft/yr (pending).

2.2 Capacity/Demand Forecast for Mitigation Planning

Monthly average rates have been used to consider impacts and mitigation by the Nisqually watershed partners as the basis for previous (successful) transfer applications. Yelm's monthly average rates are based on annual average demand that has been apportioned by month according to the City's recent (2000-05) pumping pattern.

The new demand forecast is based on Qa annual demand volumes. To assess the appropriate Qi that should be associated with the 2037 total volume of 4186 ac-ft/yr the City has evaluated a new Qi that can be associated with their recent demand forecast (Qa). Two approaches were used:

1. Using the well-capacity assumptions used in the wellfield development phasing (see Section 3): 8 wells, 750 gpm each, for 6000 gpm total.

2. Evaluating the relationship between Qa and Qi using actual pumping records.

To evaluate the actual historic pumping data to assess the relationship between Qa, Qi, and the peak month average pumping rate, we used the following procedure:

1. Golder acquired historic daily pumping records from the City for the period 2006 and 2007.

2. The peak day (maximum number of gallons per 24 hour period) was identified for the peak summer months (June, July and August).

3. The peak day volume was divided by the peak monthly volume to evaluate the relationship (correlation) between the two volumes.

4. The two ratios were averaged to develop the correlation coefficient (C), which was used for future projections.

5. The Brown and Caldwell demand forecast values (Qa, in ac-ft/yr) were converted into annual average pumping rate, and distributed among the 12-months according to the historic pattern of municipal pumping that was developed for model simulations.

6. The forecast peak month pumping (August each year) was multiplied by the correlation coefficient (C) to generate an associated Qi.

7. This projection was extended to 2037.

The resulting analysis is shown in Table 2. This forecast indicates that a Qi of 5,666 gpm is associated with the peak day pumping rate in 2037. The 4181 ac-ft/yr forecast provided by Brown and Caldwell closely matches the early projection of 4186 ac-ft/yr demand that was used in the modeling process. In addition, the 5,666 gpm Qi estimate validates the 6,000 gpm Qi associated with the eight wells projected in the water supply development plan. This analysis will move forward with 4186 ac-ft/yr Qa forecast for approximately 2037, and an associated Qi of 6,000 gpm.

,

TABLE 2
Demand Forecast by Year

Year	Qa(2)	Qa (3) Average Annual Pumping	Qi(4) Peak Day Pumping	C value(5)
	ac-ft/yr	*gpm*	*gpm*	
2006(1)	766	475	1,249	3.11e-5
2007(1)	731	453	1,059	2.74e-5
2008	819(6)	508	1,109	2.93e-5 (avg. 2006-07)
2009	843	523	1,141	
2010	1,085	673	1,469	
2011	1,187	736	1,607	
2012	1,310	807	1,761	
2013	1,410	874	1,909	
2014	1,519	942	2,056	
2015	1,629	1,010	2,205	
2016	1,747	1,083	2,365	
2017	1,867	1,157	2,527	
2018	1,987	1,232	2,690	
2019	2,107	1,306	2,852	
2020	2,228	1,381	3,016	
2021	2,329	1,444	3,152	
2022	2,430	1,507	3,289	
2023	2,532	1,570	3,427	
2024	2,635	1,634	3,567	
2025	2,737	1,697	3,705	
2026	2,855	1,770	3,864	
2027	2,994	1,856	4,053	
2028	3,112	1,929	4,212	
2029	3,231	2,003	4,373	
2030	3,350	2,077	4,534	
2031	3,469	2,151	4,695	
2032	3,588	2,224	4,857	
2033	3,707	2,298	5,018	
2034	3,826	2,372	5,179	
2035	3,945	2,446	5,340	
2036	4,064	2,520	5,501	
2037	**4,181(7)**	**2,595**	**5,666**	

Notes:

(1) Actual data were used for 2006 and 2007.
(2) B&C annual forecast demand
(3) B&C forecast demand (Qa) converted to average rate (in gpm) over the year.
(4) Peak day pumping
(5) Correlation coefficient (C) was developed to establish relationship between peak day and month and used to predict the Qi associated with the peak month (August) through the forecast period.
(6) Actual 2008 use is currently projected to be 755 ac-ft. The 819 ac-ft/yr value referenced above is forecast based on conservative assumptions.
(7) The 4181 ac-ft/yr forecast provided by Brown and Caldwell validates the 4,186 ac-ft/yr modeled to assess impacts.

3.0 PHASED APPROACH FOR NEW SUPPLY

Based on the above analysis, we developed an approach to add new pumping capacity that meets the annual and peak daily forecast demand estimated to occur in approximately 2037 (4,186 ac-ft/yr and 6,000 gpm Qi). This phased approach is intended to:

- Distribute the capital expenditures (wells) relatively evenly over time.
- Have the supply capacity (both Qa and Qi) stay ahead of the demand forecast.
- Transfer the City's downtown well pumping (and water rights) to the SW Yelm Wellfield by 2013.
- Transfer the City's new Nisqually Golf Course pumping (and water rights) to the SW Yelm Wellfield by 2018.

We have developed four phases for transfers and adding new water rights using the following assumptions for each new SW Yelm Wellfield well:

- Each well will have a peak pumping capacity of 750 gpm, sustainable for a 24-hour period (Qi). This is based on projected performance of the existing SW Wellfield #1 well.
- Each new well will have an associated water right (Qa) of 554 ac-ft/yr.

The phasing of the downtown water rights transfers is based on feedback provided by the City. The time-line of supply and demand is shown in Figure 2, and the phases are as follows:

Phase 1	2010-12	1,506 ac-ft/yr	First new SW Yelm well
Phase 2	2013-17	1,895 ac-ft/yr	Transfer downtown pumping; continue golf course pumping; two new SW Yelm wells
Phase 3	2018-24	2,770 ac-ft/yr	Transfer golf course pumping; two new SW Yelm wells
Phase 4	2025-37	4,186 ac-ft/yr	Three new SW Yelm wells

These phases formed the basis for a series of groundwater model simulations that predicted the hydrologic impacts resulting from the changes with respect to current (or "Baseline") conditions. Figure 3 projects system capacity against projected Qi requirements, based on known current well capacities, and assumed 750 gpm capacities from each new well.

4.0 SIMULATION OF FUTURE SW YELM WELLFIELD PUMPING

Golder used the latest version of the McAllister Groundwater Model (the model) to simulate the future pumping associated with the SW Yelm Wellfield development for the City of Yelm (the City). A new baseline was established reflecting current conditions to determine the impacts of the four phases of wellfield development.

The current version of the model was established in 2008 (Golder, 2008). Figure 1 shows the model domain, which is bounded to the west and east mainly by the Deschutes and Nisqually rivers, and to the north by Puget Sound. The southern boundary does not coincide with a natural hydrologic feature, but was artificially established to be sufficiently distant from the pumping wells to minimize its influence on modeled groundwater conditions when pumping changes are simulated.

4.1 Modeled Boundary Conditions

Table 3 presents the individual model boundary conditions reaches that have been established to calculate the water budget. These are shown in Figure 4. Several individual features can be combined to calculate the total groundwater discharge for a major water body.

4.1.1 Nisqually River

The model represents the groundwater discharge to the Nisqually River by a series of reaches and contributing features that include the following:

- Yelm Creek, which enters the Nisqually River near the Centralia Power
- The upper reach of the Nisqually River, which extends from the model’s southern boundary to the point where Thompson Creek enters the river
- The middle Nisqually River, which extends from the Thompson Creek inflow to the Nisqually Indian Tribe Reservation
- Kalama Springs, which feeds the middle Nisqually River reach
- The lower Nisqually River, which extends from the reservation to River Mile (RM) 4.3

An additional lower Nisqually River reach is also simulated in the model from RM 4.3 to the delta area. The model is only capable of representing discharge to the river from the Thurston County side, and does not simulate groundwater flow on the Pierce County side. No groundwater flow is deemed to occur across the river boundary below the Qpg aquifer.

4.1.2 Deschutes River

The model represents groundwater discharge to the Deschutes River also using a series of reaches and contributing features . These are:

- The upper Deschutes River, which extends from the model’s southwestern boundary to near McIntosh Lake
- The middle Deschutes River reach, which extends from McIntosh lake to Offutt Lake
- Silver Spring and Creek, which enters the middle reach of the Deschutes River
- The lower Deschutes River reach, which extends from Offutt Lake to Tumwater Falls
- Spurgeon Creek, which enters the lower reach of the Deschutes River

The model is only capable of representing discharge to the river from the Thurston County side, and does not simulate groundwater flow into the river form the west. No groundwater flow is deemed to occur across the river boundary below the Advance Vashon Outwash (Qga) aquifer.

4.1.3 Upper McAllister Valley

The model represents groundwater discharge to the Upper McAllister Valley hydrology using a series of reaches and contributing features. These are:

- The McAllister Springs complex, which consist of the major springs (McAllister and Abbott Springs, numerous smaller springs and seeps located at the headwaters of McAllister Creek)
- Groundwater discharge directly to McAllister Creek from underlying sediments
- The numerous springs and seeps that drain the east-facing slope of the McAllister Valley bluff which support the wetlands and creeks on the valley floor

4.1.4 Woodland Creek Basin

The model represents groundwater discharge to the Woodland Creek Basin hydrology using a series of reaches and contributing features. These are:

- The three kettle lakes (Long, Hicks and Pattison) and the inter-lake are wetlands that are all in hydraulic connection with shallow groundwater
- Groundwater discharge directly to Woodland Creek between the outfall at Long Lake and Henderson Inlet.

4.1.5 Other Boundary Conditions

Yelm recharges 56 ac-ft/yr 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).

TABLE 3

Model Boundary Reaches

Zone No.	Boundary Feature	Comments
1	U. McAllister Valley Springs	Tributary to McAllister Creek. Excludes McAllister Spring
2	Lake St. Clair	
3	McAllister Creek	
4	M. Deschutes River	Between Macintosh and Offutt lakes
5	McAllister Valley bluff springs	Tributary to McAllister Creek
6	L. Nisqually River – RM 4.3 to Puget Sound	Reach below minimum in stream flow point.
7	Up-gradient boundary	
8	Budd Inlet	
9	M. Nisqually River – from zone 22 to zone 33 (new U. Nisqually)	
10	Eaton Creek	Tributary to Lake St. Clair
11	Spurgeon Creek	Tributary to Deschutes River
12	Puget Sound	
14	L. Deschutes River	Downstream from new M. Deschutes reach
15	McAllister Spring	Tributary to McAllister Creek
16	Hicks Lake	Tributary to Woodland Creek
17	Long Lake	
18	Pattison Lake	
19	Long-Pattison wetland area	
20	First 5,000-ft of Nisqually above RM 4.3	
21	Second 5,000-ft of Nisqually above RM 4.3	
22	Third 5,000-ft of Nisqually above RM 4.3	
23	U. Deschutes River	Upstream from new M. Deschutes reach
24	Hicks-Pattison wetland area	Tributary to Woodland Creek
25	Woodard Creek	
26	Woodland Creek	Starts at the outlet from Long Lake
31	Kalama Creek Springs	Tributary to Nisqually River
32,34	Yelm Creek	Tributary to Nisqually River
33	U. Nisqually River	Upstream from Thompson Creek inflow. Previously included in Zone 9
35	Silver Spring and Creek	Tributary to Deschutes River

4.2 Baseline Conditions

A Baseline case was developed that involved the following pumping components:

- Downtown Yelm wells (719.66 ac-ft/yr):
    - Transfer 155.66 ac-ft/yr from the Dragt water right (which totals 189 ac-ft/yr) to the downtown wells, with 33.34 ac-ft/yr being relinquished.
    - Reduce the downtown-area well pumping by 112 ac-ft/yr per the Department of Ecology 2007 recalculation of City's historic water rights.
    - The simulated peak rate (for August) will be 747 gpm.
- New Nisqually Golf Course Well (232.61 ac-ft/yr):
    - Transfer a net 77 ac-ft/yr from the existing golf course water right of 151 ac-ft/yr (with 4.04 ac-ft/yr being relinquished); 70 ac-ft/yr of the existing irrigation right will remain at the golf course.
    - Transfer a net 155.61 ac-ft/yr from the McMonigle water right of 318.8 ac-ft/yr (with 33.39 ac-ft/yr being relinquished); 129.8 ac-ft/yr will remain at the McMonigle wells.
    - The simulated peak monthly average rate (for August) will be 242 gpm.

Figures 5, 6 and 7 shows the simulated potentiometric levels in the three main production aquifers (the Qga, Qpg and TQu) in August for the new baseline condition. In all three aquifers, the primary groundwater flow direction is to the north and northwest, parallel to the Nisqually River. Modeled potentiometric levels in Qga aquifer in the downtown Yelm area range from 260 to 300 feet mean sea level (msl), with a simulated level of 286 feet msl at the City's two existing downtown wells (Wells 1 and 2). Simulated heads in the Qpg aquifer range from 230 to 290 feet msl, indicating a vertical head difference between the two shallow aquifers of between 10 and 30 feet. The modeled potentiometric levels in the deeper TQu aquifer range from 210 to 275 feet msl.

4.3 Future Pumping Simulation Conditions

The City's future (beyond 2008) pumping will consist of a series of phases that incorporate (1) short-term transfers of private water rights to the downtown area, (2) adding new wells to the planned SW Yelm Wellfield, and (3) transferring the downtown water rights to the Wellfield. For the purpose of assessing hydrologic impacts, Golder developed four phases at which either new pumping or transfers occur. These are described in the following sections. Table 4 summarizes the main parts of each phase. Figure 8 shows the projected layout of the wells that will form the Wellfield.

4.3.1 Phase 1 (2010-2012) – Total of 1,506 ac-ft/yr

The first phase of the scenario will consist of the following:

- Adding 554 ac-ft/yr (Qa) of annual pumping at the first SW Yelm Wellfield well (the "Preferred" location). This well is assumed to have a peak capacity of 750 gpm, and the modeled rate for the peak month (August) will be 575 gpm.

- The anticipated peak capacity (Qi) of the supply at this time will be 3,150 gpm. However, the highest (August) modeled pumping rate (monthly averaged) will be 1,563 gpm (in August).

4.3.2 Phase 2 (2013-2017) – Total of 1,895 ac-ft/yr

This second phase consisted of the following:

- Transfer the water right pumping from downtown Wells 1 and 2 (720 ac-ft/yr) to the SW Yelm Wellfield, reducing the downtown peak capacity by 1,200 gpm.
- Adding the 720 ac-ft/yr plus an additional 388 ac-ft/yr of new water rights (1,108 ac-ft/yr total) at two new SW Yelm Wellfield wells (locations “Option 2” and SW Yelm Well 3).
- The two new wells are assumed to add 1,500 gpm in peaking capacity.
- The anticipated peak capacity (Qi) of the supply system at this time will be 3,450 gpm. However, the highest (August) modeled pumping rate (monthly averaged) will be 1,962 gpm.

4.3.3 Phase 3 (2018-2024) – Total of 2,770 ac-ft/yr

This third phase consisted of the following:

- Transfer the water right pumping from new Nisqually GC well (232.61 ac-ft/yr) to the SW Yelm Wellfield.
- Adding the 232.61 ac-ft/yr plus an additional 875.39 ac-ft/yr of new water rights (1,108 ac-ft/yr total) at two new SW Yelm Wellfield wells (SW Yelm Wells 4 and 5).
- The two new wells are assumed to add 1,500 gpm in peaking capacity (Qi).
- The anticipated peak capacity (Qi) of the supply system at this time will be 3,750 gpm. However, the highest (August) modeled pumping rate (monthly averaged) will be 2,876 gpm.

4.3.4 Final Phase (2025-2037) – Total of 4,186 ac-ft/yr

This final phase consisted of the following:

- Adding 1,416 ac-ft/yr of new water rights at three new SW Yelm Wellfield wells (SW Yelm Wells 6, 7 and 8). The three new wells are assumed to add 2,250 gpm in peaking capacity.
- The anticipated peak capacity (Qi) of the supply system at this time will be 6,000 gpm. However, the highest modeled pumping rate (monthly averaged) will be 4,345 gpm.

TABLE 4

Summary of Modeling Phases and Pumping Rates

Scenario	Downtown Wells		New Nisq GC Well		SW Yelm Wellfield Wells		
	Annual ac-ft/yr	*Peak Modeled gpm*	*Annual ac-ft/yr*	*Peak Modeled gpm*	*Annual ac-ft/yr*	*Peak Modeled gpm*	*Peak Capacity gpm*
Baseline	719.66	747(1)	232.61	242(1)	-	-	-
Phase 1 (2010-12)	719.66	747(1)	232.61	242(1)	554	575	750
Phase 2 (2013-17)	-	-	232.61	242(1)	1,662	1,721	2,250
Phase 3 (2018-24)	-	-	-	-	2,770	2,876	3,750
Final Phase (2025-37)	-	-	-	-	4,186	4,345	6,000

Notes: (1) – Actual pumping system capacity is higher. The model simulates peak average monthly pumping rates, assumed to occur in August.

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 rerun and the predicted changes in groundwater flow at the key features and levels at specific wells are calculated.

The Baseline and wellfield 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 Baseline case to assess the hydraulic effect of each scenario.

5.0 MODELING RESULTS

This section summarizes the model results of (1) changes in groundwater discharge to the key hydrologic features in the model domain and (2) changes in groundwater level in the key aquifers due to the phased changes in groundwater pumping.

5.1 Groundwater Flow Changes

Tables 5 through 8 summarize the maximum annual and summer changes in groundwater discharge to the individual hydrologic components (springs, lakes, rivers and creeks) compared to the Baseline condition. One table is included for each of Phases 1, 2, 3 and 4. Tables 9 through 12 present the model-predicted groundwater discharge changes for the main hydrologic features – the Nisqually River, the Deschutes River, the Upper McAllister Valley and the Woodland Creek Basin. In each case, these changes are the sum of several individual model boundary features (presented in Table 3). Figures 9 through 13 show the monthly changes in groundwater discharge to these for each of the four phases.

5.1.1 Yelm Creek

Figure 9 shows the monthly changes in groundwater discharge to Yelm Creek (at the point of discharge to the Nisqually River). Under Phase 1, the discharge decreases by up to 0.04 cubic feet per second (cfs) (18 gpm), with the maximum depletion occurring in the spring. Under Phases 2, 3 and 4, the discharge to the creek increases compared to the Baseline case by up to 0.27, 0.32 and 0.24 cfs, respectively (121, 144 and 108 gpm). The change from depletion to increased flow results from shifting pumping from the downtown wells to the new Southwest Wellfield wells. In these three phases, the maximum increases will all occur in spring. The maximum summertime increase in Phases 2, 3 and 4 will be 0.23, 0.28 and 0.23 cfs, respectively.

5.1.2 Nisqually River

Figure 10 shows the cumulative monthly changes in groundwater discharge to the Nisqually River above RM 4.3 for the four phases. Under Phase 1, the model predicted that the groundwater discharge will be up to 0.21 cfs (94 gpm) lower than under Baseline condition, with the maximum depletion occurring in August. Under Phases 2 and 3, the total discharge to the river will increase year-round compared to the Baseline; the maximum increases will be 0.29 and 0.25 cfs (130 and 112 gpm), respectively, both occurring in spring. The summertime increases will be up to 0.25 and 0.20 cfs. Under Phase 4, the model predicts that a decrease in groundwater discharge will occur year-round compared to the Baseline, with a maximum depletion of 0.28 cfs (126 gpm) occurring in September. However, the predicted depletions represent less than one percent of the Baseline discharge to the river in all months for Phases 1 and 4.

5.1.3 Deschutes River

Figure 11 shows the cumulative monthly changes in groundwater discharge to the entire Deschutes River above Tumwater Falls for the four phases. Under Phase 1, the groundwater discharge to the river will decrease by up to 0.14 cfs (63 gpm). Under Phase 2, the depletion will increase to up to 0.38 cfs (171 gpm), under Phase 3 to 0.71 cfs (319 gpm) and under Phase 4 to 1.16 cfs (521 gpm). All maximum depletions will occur in spring months. Only under Phase 1 will the depletions not exceed 1 percent of the baseline discharge in any months; conversely, this threshold will be exceeded in all months under Phase 4.

5.1.4 Upper McAllister Valley

Figure 12 shows the cumulative monthly changes in groundwater discharge to the upper valley hydrology for the four phases. Under Phase 1, the groundwater discharge to the river will decrease by up to 0.13 cfs (58 gpm). Under Phase 2, the depletion will increase to up to 0.37 cfs (164 gpm), under Phase 3 to 0.61 cfs (273 gpm) and under Phase 4 to 0.92 cfs (413 gpm). All maximum depletions will occur in summer months (either August or September). Only under Phase 4 will the depletions exceed 1 percent of the baseline discharge, and will do so between June and November (inclusive).

5.1.5 Woodland Creek Basin

Figure 13 shows the cumulative monthly changes in groundwater discharge to the entire Woodland Creek hydrology. This analysis assumes that the total impact to flow in the creek at Henderson Inlet is the sum of the individual impacts to all reaches noted above. Under Phase 1, the groundwater discharge to the creek will decrease by 0.01 cfs in all months. Under Phase 2, the depletion will increase to up to 0.04 cfs , under Phase 3 to 0.07 cfs, and under Phase 4 to 0.1 cfs . The maximum depletions will occur in spring (Phases 1-4). Only the phase 2, 3, and 4 summer depletions will exceed 1 percent of the baseline discharge. .

TABLE 5

Predicted Changes in Groundwater Discharge versus Baseline for Phase 1

Hydrologic Area/Feature	**Highest Seasonal Discharge Change**			**Summer Discharge Change**	
	Cfs	*%*	*month(s)*	*cfs*	*%*
Nisqually Valley					
- Yelm Creek	-0.04	-0.8	Feb-Mar	-0.03	**
- Upper reach	-0.07	-0.3	Aug	-0.07	-0.3
- Kalama Creek Spring	-0.02	-0.3	Jul-Aug	-0.02	-0.3
- Middle reach	-0.04	-0.3	Jul-Sep	-0.04	-0.3
- Lower reach (15,000-ft above RM 4.3)	-0.05	-0.2	Jul-Oct	-0.05	-0.2
Deschutes Valley					
- Upper reach	-0.08	-0.2	Feb-Mar	-0.06	-0.6
- Middle reach	-0.02	-0.2	Sep	-0.02	-0.2
- Silver Creek/Spring	-0.01	-0.6	Aug-Sep	-0.01	-0.6
- Lower reach	-0.01	-0.1	YR	-0.01	-0.1
McAllister Valley					
- McAllister Spring	-0.06	-0.2	Aug-Sep	-0.06	-0.2
- Other upper valley springs	-0.07	-0.2	Aug-Sep	-0.07	-0.2
- McAllister Creek	<0.01	-	-	<0.01	-
- Valley-bluff springs	<0.01	-	-	<0.01	-
Upland Lakes and Creeks					
- Lake St. Clair	<0.01	-	-	<0.01	-
- Long-Hicks-Pattison lakes	--0.01	-1.4	Sep	-0.01	-1.4
- Woodland Creek	<0.01	-	-	<0.01	-

Notes: YR – impacts equal for all months year-round
** - discharge switches from gaining to losing during this month

TABLE 6

Predicted Changes in Groundwater Discharge versus Baseline for Phase 2

Hydrologic Area/Feature	Highest Seasonal Discharge Change			Summer Discharge Change	
	cfs	*%*	*month(s)*	*cfs*	*%*
Nisqually Valley					
- Yelm Creek	+0.27	+5.3	Mar	+0.23	**
- Upper reach	+0.27	+1.2	Aug	+0.27	+1.2
- Kalama Creek Spring	-0.04	-0.8	Aug	-0.04	-0.8
- Middle reach	-0.09	-0.6	Aug	-0.09	-0.6
- Lower reach (15,000-ft above RM 4.3)	-0.15	-0.6	Aug-Sep	-0.15	-0.6
Deschutes Valley					
- Upper reach	-0.23	-0.7	Mar	-0.18	-1.7
- Middle reach	-0.05	-0.5	Sep-Oct	-0.05	-0.5
- Silver Creek/Spring	-0.02	-1.9	Sep	-0.02	-1.9
- Lower reach	-0.04	-0.1	Feb-Mar	-0.03	-0.3
McAllister Valley					
- McAllister Spring	-0.16	-0.6	Aug-Sep	-0.16	-0.6
- Other upper valley springs	-0.21	-0.6	Aug	-0.21	-0.6
- McAllister Creek	<0.01	-	-	<0.01	-
- Valley-bluff springs	<0.01	-	-	<0.01	-
Upland Lakes and Creeks					
- Lake St. Clair	-0.01	-0.5	Aug-Sep	-0.01	-0.5
- Long-Hicks-Pattison lakes	-0.03	-0.3	March	-0.03	-4.9
- Woodland Creek	<0.01	-	-	<0.01	-

Notes: YR – impacts equal for all months year-round
** - discharge switches from gaining to losing during this month

TABLE 7

Predicted Changes in Groundwater Discharge versus Baseline for Phase 3

Hydrologic Area/Feature	Highest Seasonal Discharge Change			Summer Discharge Change	
	Cfs	*%*	*month(s)*	*cfs*	*%*
Nisqually Valley					
- Yelm Creek	+0.32	+6.6	Feb	+0.28	**
- Upper reach	+0.31	+1.4	Jul-Aug	+0.31	+1.4
- Kalama Creek Spring	-0.06	-1.3	Aug	-0.06	-1.3
- Middle reach	-0.14	-1.0	Aug	-0.14	-1.0
- Lower reach (15,000-ft above RM 4.3)	-0.25	-1.1	Aug-Sep	-0.25	-1.1
Deschutes Valley					
- Upper reach	-0.42	-1.2	Mar	-0.34	-3.1
- Middle reach	-0.09	-0.9	Sep	-0.09	-0.9
- Silver Creek/Spring	-0.03	-3.5	Sep	-0.03	-3.5
- Lower reach	-0.06	-0.3	Dec, Feb-Mar	-0.05	-0.6
McAllister Valley					
- McAllister Spring	-0.26	-1.0	Aug-Sep	-0.26	-1.0
- Other upper valley springs	-0.34	-1.0	Aug-Sep	-0.34	-1.0
- McAllister Creek	<0.01	-	-	<0.01	-
- Valley-bluff springs	<0.01	-	-	<0.01	-
Upland Lakes and Creeks					
- Lake St. Clair	-0.01	-0.8	Jul-Sep	-0.01	-0.8
- Long-Hicks-Pattison lakes	-0.06	-.05	March	-0.06	--7.3
- Woodland Creek	-0.01	-0.1	Dec-Mar	<0.01	-

Notes: YR – impacts equal for all months year-round
** - discharge switches from gaining to losing during this month

TABLE 8

Predicted Changes in Groundwater Discharge versus Baseline for Phase 4

Hydrologic Area/Feature	Highest Seasonal Discharge Change			Summer Discharge Change	
	cfs	*%*	*month(s)*	*cfs*	*%*
Nisqually Valley					
- Yelm Creek	+0.24	+5.0	Feb	+0.23	**
- Upper reach	+0.20	+0.9	Jul-Aug	+0.20	+0.9
- Kalama Creek Spring	-0.09	-1.9	Aug	-0.09	-1.9
- Middle reach	-0.22	-1.6	Aug	-0.22	-1.6
- Lower reach (15,000-ft above RM 4.3)	-0.38	-1.6	Aug	-0.38	-1.6
Deschutes Valley					
- Upper reach	-0.71	-2.1	Mar	-0.55	-5.1
- Middle reach	-0.14	-1.5	Sep	-0.14	-1.5
- Silver Creek/Spring	-0.06	-1.5	Mar	-0.05	-5.7
- Lower reach	-0.10	-0.4	Feb-Mar	-0.07	-1.0
McAllister Valley					
- McAllister Spring	-0.40	-1.5	Aug	-0.40	-1.5
- Other upper valley springs	-0.52	-1.5	Aug	-0.52	-1.5
- McAllister Creek	<0.01	-	-	<0.01	-
- Valley-bluff springs	-0.01	-0.2	Feb-Sep	-0.01	-0.2
Upland Lakes and Creeks					
- Lake St. Clair	-0.01	-1.3	Aug	-0.01	-1.3
- Long-Hicks-Pattison lakes	-0.09	-11.5	Sep	-0.09	-11.5
- Woodland Creek	-0.01	-0.1	Feb	-0.01	-0.2

Notes: YR – impacts equal for all months year-round
** - discharge switches from gaining to losing during this month

TABLE 9

Predicted Cumulative Changes in Groundwater Discharge versus Baseline for Phase 1

Hydrologic Area/Feature	**Highest Annual Discharge Change**			**Highest Summer Discharge Change**	
	cfs	*%*	*month(s)*	*cfs*	*%*
Nisqually River					
at Thompson Creek	-0.09	-0.5	Aug-Sep	-0.09	-0.5
at RM 4.3	-0.21	-0.3	Aug	-0.21	-0.3
Deschutes River					
at Spurgeon Creek	-0.12	-0.2	Feb-Mar	-0.10	-0.8
at Tumwater Falls	-0.14	-0.2	Feb-Mar	-0.10	-0.6
McAllister Valley					
at Medicine Creek	-0.13	-0.2	Aug-Sep	-0.13	-0.2
Woodland Creek					
at Henderson Inlet	-0.01	-0.1	Mar	-0.01	-0.5

TABLE 10

Predicted Cumulative Changes in Groundwater Discharge versus Baseline for Phase 2

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 RM 4.3	+0.29	+0.4	Mar	+0.25	+0.4
Deschutes River					
at Spurgeon Creek	-0.35	-0.6	Feb	-0.29	-2.4
at Tumwater Falls	-0.38	-0.5	Feb-Mar	-0.31	-1.5
McAllister Valley					
at Medicine Creek	-0.37	-0.6	Aug	-0.37	-0.6
Woodland Creek					
at Henderson Inlet	-0.04	-0.2	Mar	-0.04	-1.5

TABLE 11

Predicted Cumulative Changes in Groundwater Discharge versus Baseline for Phase 3

Hydrologic Area/Feature	**Highest Annual Discharge Change**			**Highest Summer Discharge Change**	
	cfs	*%*	*month(s)*	*cfs*	*%*
Nisqually River					
at Thompson Creek	+0.60	+2.9	Aug	+0.60	+2.9
at RM 4.3	+0.25	+0.3	Feb-Mar	+0.20	+0.3
Deschutes River					
at Spurgeon Creek	-0.64	-1.1	Feb	-0.53	-4.5
at Tumwater Falls	-0.71	-0.8	Feb	-0.57	-2.9
McAllister Valley					
at Medicine Creek	-0.61	-0.9	Aug	-0.61	-0.9
Woodland Creek					
at Henderson Inlet	-0.07	-0.3	Mar	-0.06	-2.7

TABLE 12

Predicted Cumulative Changes in Groundwater Discharge versus Baseline for Phase 4

Hydrologic Area/Feature	**Highest Annual Discharge Change**			**Highest Summer Discharge Change**	
	cfs	*%*	*month(s)*	*cfs*	*%*
Nisqually River					
at Thompson Creek	+0.43	+2.1	Aug	+0.43	+2.1
at RM 4.3	-0.28	-0.5	Sep	-0.28	-0.5
Deschutes River					
at Spurgeon Creek	-1.06	-1.8	Feb	-0.87	-7.4
at Tumwater Falls	-1.16	-1.4	Feb	-0.94	-4.7
McAllister Valley					
at Medicine Creek	-0.92	-1.4	Aug	-0.92	-1.4
Woodland Creek					
at Henderson Inlet	-0.10	-0.5	Mar	-0.10	-4.2

5.2 Groundwater Level Changes

Figures 14 through 24 show the model-predicted changes in groundwater elevations in the Yelm area in August in response to the changes in pumping for the four phases in the three main production aquifers (the Qga, Qpg and TQu aquifers). Note: no figure is included for the Qga aquifer for Phase 1 because the changes in water level are less than 0.5 foot.

5.2.1 Qga Aquifer

Under Phases 2, 3 and 4, the pumping change will cause water levels in the Qga aquifer in the downtown area to rise by up to 5 feet in August (Figures 14, 15 and 16). This increase will result mostly due to the transfer of the shallow downtown-area pumping from the City's Wells 1 and 2, and the Nisqually Golf Course to the deeper aquifer to the southwest of the downtown area. The water level in the City's two downtown wells typically range from 25 to 35 feet bgs (see Figure 3-12 in Golder, 2006). Therefore, the new water level is unlikely to cause flooding problems in the area. This increase in water level will be maintained under Phase 4 despite the increase in deeper pumping.

5.2.2 Qpg Aquifer

The predicted change in groundwater level in the Qpg aquifer will be generally small in all four phases, reaching a maximum drawdown of no more than 3 feet within the wellfield area under Phase 4. A long-term drawdown of 1 foot will occur at a radial distance of up to 4 miles (Figure 20).

5.2.3 TQu Aquifer

In the TQu aquifer, the new wellfield will cause groundwater levels to drawdown with 6 feet under Phase 2, 8 feet under Phase 3 and 10 feet under Phase 4. Drawdowns of up to 1 foot will occur at distances of up to 5 miles from the wellfield under Phase 4 (Figure 24).

6.0 REFERENCES

Golder, 2008. Groundwater Modeling of Water Right and Transfers Applications. Prepared for the City of Yelm. January 29, 2008.