Cold Creek Aquifer Study of Surface Water / Groundwater Interactions, Phase 2

December 31, 2007

FINAL

King County

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Cold Creek Aquifer Study of Surface Water / Groundwater Interactions, Phase 2

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King Conservation District

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Water and Land Resources Division (WLRD)
King County Department of Natural Resources and Parks (KC DNRP)

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King Conservation District
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City of Redmond
City of Woodinville
Water Tenders

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1.0. INTRODUCTION

This document is intended to supplement work already completed and ongoing by the King County Department of Natural Resources & Parks – Water & Land Resources Division (KC DNRP/WLRD) as part of the Cold Creek Aquifer Study (the Study) located on NE Woodinville Duvall Rd, King County, WA (Figure 1).

Since 2005 DNRP has been studying the Cold Creek Aquifer, a source of cold water in Bear Creek and the Sammamish River. This work has been supported by a previous King Conservation District (KCD) grant, and is a component of a three-year Interlocal Agreement (ILA) with the Cities of Redmond and Woodinville. Phase 1 of the study has: installed three continuous flow gauges to quantify the surface water flow system; measured groundwater levels and temperatures in an existing well; collected water temperature and stream flow measurements in Cold Creek stream segments; installed a meteorological station for precipitation and evapotranspiration; and has provided these data to the public via the Internet.

To extend the investigation further into the subsurface and complete the study, KC DNRP/WLRD requested KCD funding to install monitoring wells, to analyze and interpret the data, and to develop recommendations for protection of critical areas of recharge to the aquifer that supplies this vital cold water. Based on the results of Phase 1 of the study, stream flows from the aquifer are now better understood. However, the groundwater flow system that lies further back (upgradient) from the springs had not been well understood, at least not sufficiently to make specific land-use recommendations.

To achieve maximum efficiency, the study was coordinated with three other KC DNRP projects: a Small Lakes Program study of nutrients in Cottage Lake and its tributaries under a Centennial Clean Water Grant, a wetland enhancement project in the Cold Creek Natural Area (CCNA) by the KC DNRP Ecological Services Unit using wetland mitigation compensation funding, and a Washington Department of Ecology Total Maximum Daily Load (TMDL) study of Bear - Evans Creeks. The study is also completely integrated into KC DNRP/WLRD’s on-going stream gauge and lake monitoring activities.

In addition, the study was conducted in coordination with other, very timely, studies, including:

- Redmond - Bear Creek Valley Groundwater Protection Committee and ILA (the implementation of Groundwater Management Planning)

By sharing data and understandings among these studies and projects, an integrated understanding and coordinated mitigation effort can be achieved to a degree not possible if the studies were not to be conducted contemporaneously and conjointly. The study aims to fill a data gap and to provide key groundwater data to all these efforts.
1.1 **Scope of Work**

Table 1 lists the tasks and purposes for the scope of work of Phase 2 of the study. These tasks allowed direct observation of aquifer conditions and flow directions and data were compiled and integrated from the existing stations, new equipment, and coordinated studies. Most of the effort was performed using KC DNRP/WLRD technical staff. The monitoring wells were installed using an inter-departmental contract with KC Department of Transportation (KC DOT) geotechnical specialists, contract drillers, and survey crews.

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Purpose / deliverables</th>
<th>Status</th>
</tr>
</thead>
</table>
| 1    | Compile data in existing stations and analyze | • Review / analyze data from existing stations  
      • Present approach to GPC  
      • Data available on Internet | • Completed  
      • Completed  
      • Completed |
| 2    | Install monitoring wells, survey elevations | • Observe aquifer conditions directly  
      • Estimate flow directions and gradients in aquifer | • Completed  
      • Completed |
| 3    | Collect data in new stations | • Information on subsurface conditions  
      • Preliminary HSPF modeling | • Completed  
      • Not completed |
| 4    | Analyze data and prepare report with findings and recommendations | • Interpretation and recommendations  
      • Final Report (includes all data)  
      • Present to Groundwater Protection Committee | • Completed  
      • This Report  
      • Completed |

Public involvement and discussions with Cities and the public were accomplished (without additional cost to the project) using on-going contacts on the Redmond - Bear Creek Valley Groundwater Protection Committee, which includes members from the Cities of Redmond and Woodinville, from the Water Tenders environmental organization, from local water purveyors, and from the general public.

1.2 **Setting**

The recharge area for the Cold Creek Aquifer is generally known to lie in the northern part of the county, in the vicinity of Woodinville, unincorporated King County, and Redmond. This area gradates between rural density to suburban, almost urban, residential densities. Much of the area is already supplied with municipal water, mainly from the Woodinville Water District (that obtains water from Seattle), and generally relies on septic system waste disposal. There is little commercial agriculture active in the study area, with a few horse or hobby farms.

The main water bodies in the study area are Cottage Lake, Basset Pond, Lake Leota, and Cold, Daniels and Cottage Lake Creeks (Figure 1 and 2).
Topography in the study area ranges from about 235 to about 330 ft mean sea level (MSL), between Cottage Lake and Lake Leota, respectively. To the west of Lake Leota, elevations increase steeply to about 540 ft MSL within about 1,000 ft distance.

Vegetation cover is mostly grass lawns and trees in residential areas as seen in Figure 3. Vegetation in the CCNA is dominated by grasses, bushes, and stands of trees. Although construction for a KC DNRP wetlands mitigation project (Figure 4) was recently completed in August 2007, staking and planting, invasive plant removal and wetland monitoring will continue for another 10 years.
2.0. FIELD ACTIVITIES

2.1 Site Reconnaissance

Monitoring stations were sited in the Cold Creek Study area during both Phases 1 and 2, as well as some monitoring locations that predated the study. Data from all these stations was compiled and used in the assessment. The area shown in Figures 5 through 8 depicts the area visited during field reconnaissance and shows all station types. Table 2 lists a summary of all details for all stations.

Table 2. Monitoring Station Details

<table>
<thead>
<tr>
<th>Station ID</th>
<th>Description</th>
<th>Active (Y or N)</th>
<th>Precipitation</th>
<th>Water Temperature</th>
<th>Flow Rate</th>
<th>Air Temperature</th>
<th>Water Level</th>
<th>Easting, X</th>
<th>Northing, Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>MONITORING WELL</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL_MW1</td>
<td>Site CL_MW1 - Cold Creek MW 1 GW Observation Well</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>1329508.9</td>
<td>278640.563</td>
</tr>
<tr>
<td>CL_MW2</td>
<td>Site CL_MW2 - Cold Creek MW 2 GW Observation Well</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>1327074.4</td>
<td>277071.638</td>
</tr>
<tr>
<td>CL_MW3</td>
<td>Site CL_MW3 - Cold Creek MW 3 GW Observation Well</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>1326161.9</td>
<td>278750.415</td>
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<tr>
<td>CL_MW4</td>
<td>Site CL_MW4 - Cold Creek MW 4 GW Observation Well</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>1325553.4</td>
<td>278115.34</td>
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<td>CLIMATE STATION</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>02w</td>
<td>Site 02w Cottage Lake Rain Gauge Precipitation Gauge</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1333725</td>
<td>278826</td>
</tr>
<tr>
<td>CL_MET</td>
<td>Gage: CL_MET - Cold Creek Met Station</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>1329534</td>
<td>276080</td>
</tr>
<tr>
<td>STREAM GAGING STATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>02g</td>
<td>Site 02g - Cottage Lake Creek at NE 132nd ST SG</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>1331965</td>
<td>264258</td>
</tr>
<tr>
<td>02h</td>
<td>Site 02h Cold Creek near Cottage Creek SG</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>1329615.2</td>
<td>276210.246</td>
</tr>
<tr>
<td>02K</td>
<td>Site 02K Cold Creek Below Spring SG</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>1327770</td>
<td>277872</td>
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<tr>
<td>02L</td>
<td>Site 02L Cottage Creek at NE 159th ST SG</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>1332719</td>
<td>273496</td>
</tr>
<tr>
<td>70a</td>
<td>Site 70a Big Bear Creek Tributary 0127 Above Cottage Lake SG</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>1332342</td>
<td>278089</td>
</tr>
<tr>
<td>70b</td>
<td>Site 70b Daniels Creek above Cottage Lake SG</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>1329560</td>
<td>279591</td>
</tr>
<tr>
<td>70c</td>
<td>Site 70c Cottage Lake Creek at Cottage Lake Outlet SG</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>1330350</td>
<td>275696</td>
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</table>
## Table 2. Monitoring Station Details (continued)

<table>
<thead>
<tr>
<th>Station ID</th>
<th>Description</th>
<th>Active (Y or N)</th>
<th>Data Collected</th>
<th>State Plane</th>
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<tbody>
<tr>
<td></td>
<td>Precipitation, Water Temperature, Flow Rate, Air Temperature, Water Level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Easting, X</td>
<td>Northing, Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>STREAM GAGING STATION (continued)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70d</td>
<td>Site 70D Daniels Creek above Woodinville - Duvall RD SG</td>
<td>Y</td>
<td>Y</td>
<td>Y N Y N</td>
</tr>
<tr>
<td>12123100</td>
<td>USGS 12123100 CottageLake Creek AB Bear Creek near Redmond, WA</td>
<td>N</td>
<td>N</td>
<td>N Y N N</td>
</tr>
<tr>
<td>12123000</td>
<td>USGS 12123100 CottageLake Creek AB Bear Creek near Redmond, WA</td>
<td>N</td>
<td>N</td>
<td>N Y N N</td>
</tr>
<tr>
<td><strong>WATER TEMPERATURE STATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>02i</td>
<td>Site 02i - Cottage Creek WTR</td>
<td>Y</td>
<td>Y</td>
<td>N N N N</td>
</tr>
<tr>
<td>CL10</td>
<td>Site CL10 - Daniels Creek trib at NE 175 WTR</td>
<td>Y</td>
<td>Y</td>
<td>N N N N</td>
</tr>
<tr>
<td>CL11</td>
<td>Site CL11 - Cold Creek trib at NE 175, north WTR</td>
<td>Y</td>
<td>Y</td>
<td>N N N N</td>
</tr>
<tr>
<td>CL12</td>
<td>Site CL12 Cold Creek trib at NE 175th, south WTR</td>
<td>Y</td>
<td>N</td>
<td>Y N N N</td>
</tr>
<tr>
<td>CL13</td>
<td>Site CL13 - Daniels Creek east trib at Woodinville-Duvall Rd WTR</td>
<td>Y</td>
<td>N</td>
<td>Y N N N</td>
</tr>
<tr>
<td>CL14</td>
<td>Site CL14 - Cold Creek trib at NE 165 WTR</td>
<td>Y</td>
<td>N</td>
<td>Y N N N</td>
</tr>
<tr>
<td>CL15</td>
<td>Site CL15 - Cottage Lake Creek at NE 165 WTR</td>
<td>Y</td>
<td>N</td>
<td>Y N N N</td>
</tr>
<tr>
<td>CL16</td>
<td>Site CL16 - Cottage Lake Creek at NE 187 WTR</td>
<td>Y</td>
<td>N</td>
<td>Y N N N</td>
</tr>
<tr>
<td>CL18</td>
<td>Site CL18 - Daniels Creek Side Channel South WTR</td>
<td>Y</td>
<td>N</td>
<td>Y N N N</td>
</tr>
<tr>
<td>CL20</td>
<td>Gage: CL20 - Cold Creek below 02H</td>
<td>Y</td>
<td>Y</td>
<td>N N N N</td>
</tr>
<tr>
<td>CL21</td>
<td>Gage: CL21 - Cold Creek above Cottage Lk Creek Confluence</td>
<td>Y</td>
<td>Y</td>
<td>N N N N</td>
</tr>
<tr>
<td>CLK005000</td>
<td>Site CLK0050000 Cottage Lake Creek located on east side of creek directly</td>
<td>Y</td>
<td>N</td>
<td>Y N N N</td>
</tr>
<tr>
<td>00</td>
<td>underneath large culvert beneath NE 124th St. WTR</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- 12123100 using NAD27 datum
- WTR = Water Temperature Recorder
- SG = Stream Gauge
- GW = Groundwater
- * = Monitoring well
- Rd = road
- trib = tributary
- Obs. = Observation

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*December 2007*
2.2 Monitoring Wells

Well construction details for all wells monitored are listed in Table 2. Monitoring well CL_MW1 is a private well that has been monitored by KC DNRP/WLRD for the past two years. Locations for newly installed monitoring wells were sited and cleared for utilities. A licensed well driller, Holocene Drilling Inc., was contracted to install three monitoring wells, CL_MW2, CL_MW3, and CL_MW4, using the hollow stem auger drilling method at the locations marked in Figure 8. Wells were installed between September 26 through 28, 2007. During well installation, borehole lithology was recorded and is shown in well logs in Appendix A. Pictures of the wells are included in Appendix B. The Unified Soil Classification System (USCS) was used for sediment description and a summary of the borehole lithology is presented in Table 3.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Sand Pack Depth</th>
<th>Screen Depth</th>
<th>Borehole Depth (BHTD)</th>
<th>Depth to Water (ATD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Depth (ft)</td>
<td>USCS Symbol</td>
<td>(ft)</td>
<td>(ft)</td>
</tr>
<tr>
<td>CL_MW2</td>
<td>0 - 1.5</td>
<td>Fill</td>
<td>21 - 35</td>
<td>25 - 35</td>
</tr>
<tr>
<td></td>
<td>1.5 - 8</td>
<td>SM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 - 16</td>
<td>SP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16 - 21</td>
<td>SW</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>21 - 28</td>
<td>SP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28 - BHTD</td>
<td>GP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL_MW3</td>
<td>0 - 0.5</td>
<td>Topsoil</td>
<td>14 - 30</td>
<td>20 - 30</td>
</tr>
<tr>
<td></td>
<td>0.5 - 9</td>
<td>SM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 - BHTD</td>
<td>SP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CL_MW4</td>
<td>0 - 0.5</td>
<td>Road Gravel</td>
<td>74 - 89.5</td>
<td>79.5 - 89.5</td>
</tr>
<tr>
<td></td>
<td>0.5 - 79</td>
<td>SM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>79 - BHTD</td>
<td>SP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
ATD = At time of Drilling
ft = feet
USCS = Unified Soil Classification System

2.3 Equipment Installation & Maintenance

2.3.1 Monitoring Wells

All wells were outfitted with continuous water level data loggers. Data loggers were set to collect data on a 15-minute frequency at each well for water temperature and water level.
2.3.2 Other Monitoring Stations

Precipitation, air temperature, water temperature data and continuous flow measurement data loggers had been installed at stations as part of the KC DRNP/WLRD hydrologic monitoring program or Phase 1 of this study. No additional installation of logging equipment was required during Phase 2 of this study. Maintenance on data logging equipment and the stations were conducted as part of the regular maintenance program on an as-needed basis.

2.4 Data Logger Download

Data was manually downloaded at each station on at least a quarterly basis. Data from the monitoring well water level data loggers were collected for about a two month period.

2.5 Surveying

Locations for monitoring wells were surveyed by KC Department of Transportation - Roads Services Division (KC DOT/RSD) personnel to the Washington state plane coordinate system and datum. Table 2 lists the coordinates for all stations used in this study. Other station types were located as part of earlier work by the KC DNRP/WLRD Hydrologic Team.
3.0. RESULTS & DISCUSSION

3.1 Stream Gauge & Water Level Data

Inflow and outflow to the basin is displayed in the stream gauge data graphed in Figure 9. During the critical fish window between September 15 and October 15 of 2006 and 2007, most of the flow out of the basin is seen entering the basin at stream gauge station 02K, very close to the springs discharge point. Input from other sources are on an order of magnitude lower than at stream gauge station 02K.

Figure 10 shows that there is virtually no delay in response between a precipitation event and water levels in monitoring well CL_MW1. Water levels in the well track close to the precipitation events consistently over the two years shown (2006 & 2007). A simplified model was developed for this data. This model assumes water enters and exits without the effects of evapotranspiration, effects of groundwater levels on flows, and other complex factors. Precipitation was analyzed to make consistent with groundwater data. For every 1 inch of precipitation, a 1.7 inch rise in groundwater level is observed in CL_MW1. Along the bottom of the chart area in Figure 10, monthly precipitation totals are shown. Exceedances of 3.65 inches per month are underlined – during these months with above the 3.65 inches the water level in CL_MW1 rose, during all the months with less than 3.65 inches the water level dropped. Note that in December 2007, although only four days of data were shown, the month’s precipitation exceeds the value.

This observed relationship between precipitation and groundwater levels in monitoring well CL_MW1 is not only a local phenomenon, but was also observed in all new monitoring wells. All wells showed water levels that tracked closely and quickly to precipitation (Figure 11). There are also fluctuations around the trend line in all the wells, which appear to be related to barometric pressure (a phenomenon called “barometric efficiency”). The fluctuations in monitoring well CL_MW4 are much greater than in other wells, as indicated by the larger swings in the pink line on the graph. The aquifer at the location screened in this well is confined and the barometric efficiency is therefore greater. An anomaly occurred in monitoring well CL_MW3 after the high precipitation event in December 2007 (Figure 11). This is likely a local flow phenomenon caused by increased local recharge in the stormwater retention pond adjacent to the well.

The calculated flow direction in the study area, based on the four wells used in this study, is toward E31°S (Figure 12). This agrees well with data reported by Hart Crowser (HC 1993 & 1994), but is more southerly than reported by Golder (Golder, 2007). Flow gradients are at 0.0040 ft/ft (or 22 ft/mile). In addition, a groundwater divide was suggested for the area west of Cottage Lake (Golder, 2007). Data reported here does not rule out that possibility.

Figure 13 shows an example of the diurnal water level fluctuations in monitoring well CL_MW1. Data was recorded on a 15-min frequency over 24-hours. An average over 266 days was calculated and a trend line of a 24 hour moving average plotted on Figure 13. Apparent drawdown of ¼ inch occurs between 5:15 am and 8:45 am and between 3:30 pm and 10:00 pm.
This drawdown was determined to be a mainly global meteorological (barometric) phenomenon. The effect of diurnal surface pressure waves are shown in Figure 13 compared to work completed by UW scientists, Mass, Steenburgh & Schultz (1991).

An additional simple model was run, using the USGS “hydrograph separation” method. Figure 14 shows that baseflow is a high percentage of total flow in the basin, as evidenced by the stream gauge station 02K data. In addition, the whole basin is shown as intermediate (i.e. station 12123000). The flows shown at other locations are mostly runoff.

Should additional modeling be considered, there are a few unpredictable phenomena to note. Figure 15 shows how monthly average water levels (taken between June 1996 & January 2007) rise throughout the summer at stream gauge 02H near the bridge in the wetland as compared to data from a more normal responding stream gauge (02g). This is possibly due to channel obstruction by nightshade, reed canary grass, or beaver dams. Another phenomenon is caused by lakeside resident(s) occasionally removing beaver dams. This complicates the analysis since the behavior is not predictable. For example, in April of 2006, as precipitation occurred, outflows increased and the lake level dropped, before and during the high rainfall event on April 21, 2006 (Figure 16).

### 3.2 Temperature Data

Surface water temperatures at all stream gauge stations showed a consistent gradation (Figure 17). Surface water temperatures were warmer in the summer and colder in the winter at all stream gauge stations. However, fluctuations at stream gauge station 02K were much less than at all other stations. In addition, temperatures in 02K during the summer are much lower than at any other stream gauge station. Figure 17 also shows that 02K provides most of the water in the basin and most of the cold water in the basin.

Observations in monitoring well CL_MW1 indicated that temperatures are warmer in the winter and cooler in the summer by about one degree. The average temperature is a little warmer than at stream gauge station 02K. Surface heating is warmer in the summer, but by the time that heat reaches the depths in the aquifer that are screened in monitoring well CL_MW1 it is winter, and vice versa for cool winter surface temperatures reaching depths of the well in summer so the water is cooler at depth (Figure 17). The effect of the summer heating is seen at about 180º out of phase during the winter months.

All new monitoring wells (CL_MW2, CL_MW3, and CL_MW4) showed the same trend of rising temperatures over the fall (October through December 2007). Whereas, monitoring well CL_MW4, which is screened at much greater depth, did not show increasing or decreasing trends in groundwater temperature.

Figure 18 also shows a trend of cooler temperatures to the south, possibly due to warmer recharge from Lake Leota in the north or perhaps due to deeper flow paths to the south. This may explain the previous observation that the stream water temperatures at the more southerly 02K, despite having exposure to air temperatures between springs and the 02K gauge, are lower than the groundwater temperatures at the more northerly CL_MW1.
In Figure 18, the results for monitoring well CL_MW3 show a sharp rise and fall in groundwater temperature at around December 3, 2007. This is possibly due to recharge from high precipitation event that filled the adjacent stormwater retention pond.

### 3.3 Borehole Lithology

The recharge area for the Cold Creek Aquifer is generally known to lie in the northern part of the King County, in the vicinity of Woodinville, unincorporated King County, and Redmond. The surficial geologic map in Figure 19 shows mostly till (Qvt), advance and recessional outwash deposits (Qva and Qvr, respectively), and wetland deposits (Qw) at the surface in the study area. The conceptual hydrogeologic model for this area, shown in Figure 20, shows water moving downgradient from the uplands into advance outwash deposits (Qva) and recessional outwash deposits (Qvr) from the northwest and from Lake Leota and discharges into Cold Creek and Cottage Lakes.

Sediment descriptions collected during well installation are listed in Table 3. More detailed descriptions, along with site and sediment photos, are presented in Appendix A and B, respectively. Lithology in the boreholes were as expected; till (Qvt), advance outwash deposits (Qva), and the recessional outwash deposits (Qvr). The conceptual hydrogeologic model in Figure 20 was supported by the findings of this study.
4.0. RECOMMENDATIONS

Modeling is recommended for the overall water balance of the basin, including the changes in Cottage Lake level, flows in and out via surface channels, and evapotranspiration based on CL_MET data. This water balance would allow an estimate of unaccounted-for groundwater inflow. This model will have to take into account the phenomena of the effects of channel obstruction by nightshade and reed canary grass, and the construction and destruction of or beaver dams.

Other than the following, there is no planned future actions related to this study. Transducers are currently collecting data from the monitoring wells. Data will be downloaded and made available on the website on an annual basis or as funding allows. Some gauging of the streams may continue as part of the regular KC program.
5.0. REFERENCES & CITATIONS


King County Department of Natural Resources & Parks – Water & Land Resources (KC DNRP/WLRD). 2005. *Cold Creek Aquifer Study of Surface Water / Groundwater Interactions, Phase 2; Grant Application*. Submitted to King Conservation District Member Jurisdiction & WRIA Forum.

Figures
Figure 1. Area Map.
Figure 2. Detailed Map of Study Area.
Figure 3. Vegetation Setting.
Figure 4. Wetland Mitigation Project: Planned Restoration in Cold Creek Natural Area.

- Bassett Pond
- Hardhack interplanting
- Willow & dogwood
- Control Reed Canary Grass, plant appropriate species
Figure 5. Stream Gauge Stations.

The information included on this map has been compiled by King County staff from a variety of sources and is subject to change without notice. King County makes no representations or warranties, express or implied, as to accuracy, completeness, timeliness, or rights to the use of such information. This document is not intended for use as a survey product. King County shall not be liable for any general, special, indirect, incidental, or consequential damages including, but not limited to, lost revenues or lost profits resulting from the use or misuse of the information contained on this map. Any sale of this map or information on this map is prohibited except by written permission of King County.
Figure 6. Climate Stations.
Figure 7. Water Temperature Stations.
Figure 8. Monitoring Well Locations.
Figure 9. Stream Flows

- **02L** at NE 159th at basin outlet
- **02G** at NE 132nd far downstream
- **02K** Cold Creek Springs inflow to basin
- **70A** Cottage Lake Creek inflow to basin
- **70D** Daniels Creek inflow to basin

Fish critical window: 9/15 - 10/15
Figure 10. Groundwater Levels at Monitoring Well CL_MW1 & Precipitation

Water Level in CL_MW-1 Well in Cold Creek Natural Area

Precipitation

0.2"/d recession
3.65"/month

Monthly precipitation totals:

<table>
<thead>
<tr>
<th>Date</th>
<th>Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/20/07</td>
<td>2.46</td>
</tr>
<tr>
<td>1/3/08</td>
<td>3.65</td>
</tr>
<tr>
<td>4/2/08</td>
<td>3.70</td>
</tr>
<tr>
<td>8/2/07</td>
<td>4.71</td>
</tr>
</tbody>
</table>

12/07: 4 days only!
Figure 11. Precipitation and Relative Water Levels in Monitoring Wells

Anomaly after severe rain, especially at CL_MW3, which is adjacent to surface water.

Water levels in all four wells track closely.

Precipitation at 02w (up to 12/4), scaled to historical trend.
Figure 12. Flow Direction and Water Level Elevations.
Figure 13. Diurnal Surface Pressure Wave

Diurnal Groundwater Level Fluctuations:
Well CL_MW-1
12/30/05 - 1/5/07

Paper by UW atmospheric scientists: Mass, Steenburgh, & Schultz (1991)
Figure 14. Correlation of Precipitation and Groundwater Levels

Baseflow as a percentage of total flow (quarterly estimates)
using USGS "Hydrograph Separation" method

12123000 = basin outflow (intermediate)
70c = outflow from Cottage Lake
02K = springs
02L = basin outflow (near)
02g = 12123100 = far downstream
70a, 70b, 70d = inflows above Cottage Lake

King County 30 December 2007
Figure 15. Gate 02H at Bridge in Wetland

[Diagram showing water levels over time, with annotations:
- Water levels rise through summer
- Possibly channel obstruction by nightshade, reed canary grass, or beaver dams
- Compare to more normal gage = 02g (Cottage Lake Crk at NE 132nd St)]
Figure 16. Effects of Beaver Dam Removal
Figure 17. Stream Water Temperatures

Fish Critical Window:
Sept 15 - Oct 15

Well = GW Temperature

Air Temperature
(at 02K)

02K = Cold Creek springs
Figure 18. Groundwater Temperatures

CL_MW1 -- existing (35' deep) well

CL_MW3 -- 33' deep well near R/D pond

CL_MW4 -- 68' deep well

CL_MW2 -- 37' deep well

also, more southerly wells seem to be colder, perhaps due to deeper flow paths
Figure 19. Surficial Geologic Map.

Reference figure from UW, GeoMapNW 2006
Figure 20. Conceptual Hydrogeologic Cross Section

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Appendix A

Well Logs
## LOG OF MONITOR WELL INSTALLATION

**WELL NO. MW-2**

**PROJECT:** Cold Creek Aquifer Study  
**BORING LOCATION:** Refer to notes below.  
**DRILL METHOD:** Hollow Stem Auger  
**DRILLER:** Holocene Drilling Inc.  
**DEPTH TO:** Water: 16.16 ft  
**DATE:** September 28, 2007  
**START:** 9:00 AM  
**FINISH:** 2:30 PM  
**LOGGER:** D. Armstrong  
**DATE CHECKED:** End of shift

<table>
<thead>
<tr>
<th>ELEVATION/DEPTH</th>
<th>SOIL SYMBOLS AND FIELD TEST DATA</th>
<th>USCS</th>
<th>DESCRIPTION</th>
<th>MOIST (%)</th>
<th>-200 (%)</th>
<th>REMARKS</th>
<th>MONITOR WELL CONSTRUCTION SCHEMATIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>290</td>
<td>SM</td>
<td></td>
<td>Brown poorly graded sand with gravel, moist, medium dense. (Fill)</td>
<td></td>
<td></td>
<td></td>
<td>Wellhead completed above grade.</td>
</tr>
<tr>
<td>285</td>
<td>SM</td>
<td></td>
<td>Brown silty sand with gravel, wet, medium dense.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>275</td>
<td>SP</td>
<td></td>
<td>Gray brown silty sand with gravel, moist to wet, dense.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>270</td>
<td>SP</td>
<td></td>
<td>Brown poorly graded medium-grained sand, moist, medium dense.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>265</td>
<td>SW</td>
<td></td>
<td>Brown well graded sand with gravel, moist.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>260</td>
<td>SP</td>
<td></td>
<td>Dark brown poorly graded medium to coarse grained sand with gravel, wet, dense to very dense.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>255</td>
<td>GP</td>
<td></td>
<td>Dark poorly graded fine gravel with sand, wet, very dense.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MW-2 is located between the residences at 17208 174th Ave. NE and 17314 174th Ave. NE. Groundwater was encountered at 16.5 feet below the surface during drilling. The Department of Ecology well identification number is: APF 086.
### LOG OF MONITOR WELL INSTALLATION

**WELL NO. MW-2**

(Continued)

<table>
<thead>
<tr>
<th>ELEVATION/DEPTH</th>
<th>SOIL SYMBOLS AND FIELD TEST DATA</th>
<th>USCS</th>
<th>Description</th>
<th>Moist (%)</th>
<th>-200 (%)</th>
<th>Remarks</th>
<th>Monitor Well Construction Schematic</th>
</tr>
</thead>
<tbody>
<tr>
<td>255</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>225</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>220</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>215</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**PLATE 1**

KING COUNTY MATERIALS LABORATORY
**LOG OF MONITOR WELL INSTALLATION**

**WELL NO. MW-3**

**PROJECT:** Cold Creek Aquifer Study  
**BORING LOCATION:** Refer to notes below.  
**DRILL METHOD:** Hollow Stem Auger  
**DRILLER:** Holocene Drilling Inc.  
**DEPTH TO - Water:** 12.11 ft  
**DATE:** September 26, 2007  
**START:** 10:00 AM  
**FINISH:** 3:00 PM  
**LOGGER:** D. Armstrong  
**DATE CHECKED:** 9/27/07

<table>
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<th>ELEVATION/DEPTH</th>
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<th>USCS</th>
<th>Description</th>
<th>Moist (%)</th>
<th>-200 (%)</th>
<th>Remarks</th>
<th>Monitor Well Construction Schematic</th>
</tr>
</thead>
<tbody>
<tr>
<td>305</td>
<td></td>
<td>SM</td>
<td>Sod and Topsoil. Brown silty sand with gravel, moist, medium dense.</td>
<td></td>
<td></td>
<td>Wellhead completed above grade.</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>295</td>
<td></td>
<td>SM</td>
<td>Gray silty sand with gravel, moist, dense. (Noted the change in the drill cuttings)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>290</td>
<td></td>
<td>SP</td>
<td>Brown poorly graded medium to coarse- grained sand, moist to wet, dense to very dense.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MW-3 is located along the south side of the detention pond, which is in the northwest quadrant of the intersection of 171 Ave NE and NE 170th Street. Groundwater was encountered at 14 feet below the surface during drilling. The Department of Ecology well identification number is: APF 062.

KING COUNTY MATERIALS LABORATORY

PLATE 2
**LOG OF MONITOR WELL INSTALLATION**  
**WELL NO. MW-4**

**PROJECT:** Cold Creek Aquifer Study  
**BORING LOCATION:** Refer to notes below.  
**DRILL METHOD:** Hollow Stem Auger  
**DRILLER:** Holocene Drilling Inc.  
**DEPTH TO - Water:** 68.22 ft

<table>
<thead>
<tr>
<th>ELEVATION/DEPTH</th>
<th>SOIL SYMBOLS</th>
<th>SAMPLER SYMBOLS AND FIELD TEST DATA</th>
<th>USCS</th>
<th>Description</th>
<th>Moist (%)</th>
<th>&lt;200 (%)</th>
<th>Remarks</th>
<th>Monitor Well Construction Schematic</th>
</tr>
</thead>
</table>
|                 | SM           |                                     |      | Crushed Surfacing Top Course.  
(Soulder Gravel)            |           |           |          |          |         |                                   |
|                 | SM           |                                     |      | Dark brown silty sand with gravel, moist to wet, loose.  |           |          |         |                                   |
|                 | SM           |                                     |      | Brown silty sand with gravel, moist, loose to medium dense.  
Gray silty sand with gravel, moist, medium dense to dense.  |           |          |         |                                   |
|                 | SM           |                                     |      | Gray silty sand with gravel, moist to wet, very dense.  
(Glacial Till)            |           |          |         |                                   |

MW-4 is located in front of the residence at 16904 NE 176th Street. Groundwater was encountered at 70 feet below the surface during drilling. The Department of Ecology well identification number is: APF 070.

PLATE 3

KING COUNTY MATERIALS LABORATORY
**LOG OF MONITOR WELL INSTALLATION**

**WELL NO. MW-4**

(CONTINUED)

<table>
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<tr>
<th>ELEVATION/DEPTH</th>
<th>SOIL SYMBOLS</th>
<th>USCS</th>
<th>Description</th>
<th>Moist (%)</th>
<th>-200 (%)</th>
<th>Remarks</th>
<th>Monitor Well Construction Schematic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SM</td>
<td>Gray poorly graded medium to coarse-grained sand, moist, very dense. This layer contains lenses of gravel.</td>
<td>15,39,44</td>
<td>17,60,55/5</td>
<td></td>
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</tbody>
</table>

**PLATE 3**

KING COUNTY MATERIALS LABORATORY
## LOG OF MONITOR WELL INSTALLATION

**WELL NO. MW-4**

(Continued)

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<th>Description</th>
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<th>-200 (%)</th>
<th>Remarks</th>
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</thead>
<tbody>
<tr>
<td>285</td>
<td></td>
<td>SP</td>
<td>Brown poorly graded sand, wet, very dense.</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>280</td>
<td></td>
<td></td>
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PLATE 3

KING COUNTY MATERIALS LABORATORY
### KEY TO SYMBOLS

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<th>Symbol</th>
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</thead>
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<td><strong>Strata symbols</strong></td>
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<tr>
<td></td>
<td>Topsoil</td>
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<tr>
<td></td>
<td>Silty sand</td>
</tr>
<tr>
<td></td>
<td>Poorly graded sand</td>
</tr>
<tr>
<td></td>
<td>Crushed Surfacing Top Course</td>
</tr>
<tr>
<td></td>
<td>Well graded sand</td>
</tr>
<tr>
<td></td>
<td>Poorly graded gravel</td>
</tr>
<tr>
<td></td>
<td><strong>Misc. Symbols</strong></td>
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<td></td>
<td>Water table during drilling</td>
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<tr>
<td></td>
<td>Bottom of Boring</td>
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<tr>
<td></td>
<td>Boring continues</td>
</tr>
<tr>
<td></td>
<td><strong>Soil Samplers</strong></td>
</tr>
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<td></td>
<td>Standard penetration test</td>
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<tr>
<td></td>
<td><strong>Monitor Well Details</strong></td>
</tr>
<tr>
<td></td>
<td>flush-mount cover</td>
</tr>
</tbody>
</table>

### Notes:

1. The observation wells were drilled between September 26 and September 28, 2007 using a truck mounted Mobile B-59 drill equipped with hollow stem auger.

2. The observation wells will be located and elevations measured by survey.

3. These logs are subject to the limitations, conclusions, and recommendations in this report.
Appendix B

Pictures
CL_MW1 Monitoring Well (continued)
CL_MW2 Monitoring Well

Level drilling

CL_MW2 Monitoring Well (continued)
CL_MW4 Monitoring Well

CL_MW4 Monitoring Well (continued)

Monitoring well CL_MW4, along NE 179th

Completed flush-mounted monitoring box (shown with water level meter)
Daniels Creek at Woodinville-Duvall Rd

Cottage Lake Creek at NE 159 (continued)
CL_MET Station

02K Stream Gauge Station