TRILOGY AND REDMOND RIDGE URBAN PLANNED DEVELOPMENT (UPD) ANNUAL MONITORING REPORT: WATER YEAR 2007

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King County
Department of Natural Resources and Parks
Water and Land Resources Division

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Executive Summary

Trilogy (formerly Blakely Ridge) and Redmond Ridge (formerly Northridge) are adjoining Urban Planned Developments (UPDs) located on approximately 2560 acres (1035 hectares) in north central unincorporated King County, Washington. This report presents the results from natural resource monitoring conducted during the 2007 water year (i.e., October 1, 2006 through September 30, 2007) at the UPD project site, including recommendations for corrective actions where appropriate. The methods and data collected follow recommendations specified in the original Redmond Ridge and Trilogy post-development monitoring plans.

Monitoring initiation and duration of specified parameters is often linked to 75 percent subbasin buildout. At the end of the 2007 water year, eight out of nine UPD subbasins had reached this threshold with the Big Bear Creek subbasin only at 25 percent buildout.

A major goal of the UPD monitoring program is to detect and evaluate significant changes to the natural resources as a result of UPD development, including changes to streams, wetlands, fisheries, and groundwater. The program contains elements for assessing the status of and trends in aquatic macroinvertebrates, amphibians, fish, wetland vegetation, wetland and stream hydrology, stream cross-section stability, water quality, and groundwater quality and quantity. The UPD monitoring program also evaluates whether stormwater facilities are working as designed in regard to flow control and water quality objectives.

The Trilogy and Redmond Ridge monitoring plans identify specific threshold exceedance criteria to ensure the effectiveness of protective actions. Exceedance of one or more thresholds triggers an investigation into the cause of the exceedance, and may require: (1) corrective action to mitigate project-related impacts, should the exceedances be attributable to UPD development, or (2) reconsideration of the threshold. Each threshold criterion is evaluated in this report, and recommendations are provided when exceedances are identified.

Through the 2007 water year, no corrective actions are recommended. A new threshold exceedance criterion is introduced for fish. Further evaluation is recommended for wetland and stream hydrology, stormwater facility water levels, and amphibian egg mass mortality at BBC-45d/s because of threshold exceedances. Rising conductivity and hardness levels in streams and wetlands should also be monitored closely, but no thresholds have been exceeded.

In the following subsections, the monitoring procedures and results from the current monitoring period are summarized for each representative resource monitoring objective.

Precipitation

Precipitation monitoring is conducted to provide supporting data for the interpretation of results from other monitoring activities (e.g., wetland and stream hydrology evaluation). Water year 2007 was the third wettest year on record for precipitation at Station 02V with a 12-month precipitation total of 52.06 inches (132.2 cm). The historical mean was 43.49 inches (110.5 cm). No threshold exceedance criteria are associated with precipitation and therefore no corrective actions are recommended.

Macroinvertebrates

Benthic macroinvertebrate monitoring is conducted to assess impacts to fisheries food supplies and aquatic habitat. 2007 BIBI scores at Wallace (30.7) and Adair (33.3) Creeks are within the range of predevelopment conditions and are indicative of fair biotic condition. Threshold exceedance criteria were not violated and no corrective actions are recommended.

Amphibians

Amphibian breeding surveys are conducted within five wetlands (BBC-44, BBC-45, BBC-52, BBC-26, and SR-24C) to monitor changes in native amphibian breeding species richness or egg mass abundance. 2007 species richness varied from wetland to wetland, but always fell within the previously documented range. Northern red-legged frog egg mass abundance was the highest and second highest on record at BBC-26 and BBC-52, respectively. Pacific treefrog egg mass abundance was the second highest on record at BBC-52. Northwestern salamander egg mass abundance was the highest on record at BBC-26, BBC-44, and BBC-52. No long-toed salamander egg masses, which can be difficult to find, were observed in 2007. Average egg mass mortality did not exceed 20% at any wetland with the exception of Northwestern salamanders in BBC-45d/s, which had over 67% average egg mass mortality. Although this mortality rate is the highest on record, BBC-45d/s has always had higher mortality rates than other UPD wetlands, and the mortalities cannot be conclusively linked to UPD development. No other threshold exceedance criteria were violated in 2007 and no corrective actions are recommended.

Fish

Fish abundance and species richness is monitored annually or biennially using electrofishing surveys. In 2007, 33 cutthroat trout, 74 coho salmon, 55 rainbow trout, and 12 riffle sculpin were observed at Adair Creek. This is the first observation of rainbow trout at this stream. The 33 cutthroat trout represent a decline of 72.3% from the 119 observed during the 2000 predevelopment survey, but is an increase from the 10 observed in 2006. Fish populations naturally fluctuate from year to year, and it is difficult to determine whether the abundance changes observed were the result of natural fluctuations, increased urban development, or differences in sampling efficiency. Therefore, despite exceeding fish abundance criteria set forth in the monitoring plans, no corrective actions are recommended. The threshold exceedance criteria should be changed to the following: no species present before UPD development should disappear in any sampling season.

Wetland Vegetation

No BBC-52 wetland vegetation monitoring was conducted in 2007, per the monitoring plan schedule. Monitoring will continue in 2008 following the even year sampling schedule.

Wetland Hydrology

Wetland hydrology is monitored continuously at two Trilogy wetlands (BBC-44 and SR-24B) and six Redmond Ridge wetlands (BBC-UN1, BBC-45, BBC-52, EC-61, EC-4, and EC-3). In addition, crest-stage gages are actively monitored at four Trilogy wetlands (SR-24A, SR-24C, BBC-26, and BBC-45). Results indicate several wetlands with elevated summer and/or winter water levels compared to predevelopment conditions (SR-24A, SR-24B, SR-24C, BBC-26,

BBC-45, BBC-52, and EC-3). In addition, peak water levels have increased relative to baseline conditions at SR-24C, BBC-45, and BBC-52. Gate flow control at EC-61 may need to be adjusted to address the large water level fluctuations that have been observed over short (e.g., less than 7 day) time periods. No additional corrective actions are required as wetland elevations are greatly affected by beaver activity within both UPDs. However, conditions should be monitored closely.

Stream Hydrology

Continuous streamflow monitoring is conducted within or downstream of Trilogy at five streams and two bypass gages: 02C Colin Creek North, 02D Colin Creek South, 53A Adair Creek, 53B Wallace Creek West, 53C Wallace Creek North, 53D Adair Creek Bypass and 53F Wallace Creek Bypass and within or downstream of Redmond Ridge at two streams: 18F Rutherford Creek and 18B Evans Creek Central (South Weir). The goal of this monitoring component is to assess the hydrologic performance of the streams compared to their predevelopment condition.

Wallace West, Wallace North, Colin South, and Evans Central Creeks appear to be functioning close to the designed performance. The peak flow target appears to have been exceeded in Rutherford Creek and the flow durations appear to have been exceeded in Adair, Colin North, and Rutherford Creeks. If feasible, Hydrological Simulation Program-Fortran (HSPF) models will be run with the rainfall for the gaged period to verify performance to be reported in the 2008-2010 monitoring report. No corrective actions are required; however, additional analyses may suggest corrective actions.

Stream Channel Characterization

Stream channel characterizations (i.e., longitudinal stream surveys) were included in both the Trilogy and Redmond Ridge monitoring plans to try to capture potential changes to fish habitat and downstream channel characteristics resulting from UPD development. No surveys were conducted in 2007. Because of the difficulties in obtaining landowner permission, the inherent variability of the protocols used, and the inability of the chosen methodologies to link changes to upstream development, this monitoring parameter will be discontinued.

Stream Channel Stability

Stream cross-sections are measured at established transect stations to identify areas of erosion or channel instability and to track changes in channel shape over time. Five Adair Creek cross-sections were measured in 2007. There were no statistically significant differences at any cross-sections in 2007 compared to preconstruction. In addition, differences in field data collection methodologies in 2006 and 2007 made direct comparisons of threshold exceedance criteria difficult. Resuming 1991-2005 field data collection methods is recommended for 2008 and beyond and should allow more direct comparisons of pre- and post-development conditions. No corrective actions are recommended.

Water Quality

Wetland and stream water quality sampling ensures that stormwater management facilities and other best management practices (e.g., riparian buffers) are effectively limiting pollutants in receiving surface waters. Water quality sampling follows one of two methods: (1) Annual

sampling three times between January and April at 13 wetlands and 7 streams; or (2) continuous temperature monitoring at 5 streams.

The January to April sampling reveals that although conductivity within the Big Bear Creek and Evans Central subbasins has remained within the same range between 2002 and 2007, all other subbasins exhibit some increases in conductivity relative to predevelopment conditions. The Colin North and Rutherford subbasins show the strongest increases (BBC-26 increased from less than 55 µS/cm in 2002 through 2004 to greater than 75 µS/cm in 2007; EC-3 measured less than 60 µS/cm prior to 2004 and greater than 80 from 2005 to 2007). Temperatures for all streams and wetlands maintained an average of between 6 and 9ºC at most sampling sites except BBC-26u/s, which had an average of 10.3ºC. Across the monitored streams and wetlands, pH measurements were comparable in 2002-2004 and 2007, with some elevated pH measurements observed in 2005 and 2006. Hardness measurements at wetland EC-3 have doubled since 1991; increases and decreases at other sites have been relatively small in magnitude. Alkalinity measurements show a decline between 2006 and 2007; however, this decline may represent natural year-to-year variability.

Continuous temperature monitoring suggests that stream temperatures follow predictable seasonal patterns. Predevelopment baseline conditions were not clearly established, but annual patterns have remained the same since 2001-2002 when gages were installed. Average 7-day maximum summer water temperatures are periodically above the 17.5ºC water quality criteria, likely as a result of their proximity to upstream open water wetlands.

As a result of the sampling design, the natural predevelopment variability in most field parameters is not well understood. Nevertheless, the increasing trends in conductivity and hardness across several wetland and stream locations warrant further investigation. However, no corrective actions are recommended pending the results from facility water quality performance monitoring scheduled to be implemented in water year 2008.

Welcome Lake Trophic State

Welcome Lake is located to the northwest and downstream from the Trilogy and Redmond Ridge UPDs and is the only lake receiving runoff from these developments. Annual monitoring is focused on whether UPD development is affecting the trophic state of Welcome Lake. 2007 was the first full year after the 75% buildout threshold and the trophic state index (TSI) was 45.0. This appears to be an improvement over the pre-UPD construction range of 46.5 (2000) to 52.0 (1996). No corrective actions are recommended.

Sediment Analysis

Analysis of sediments is useful for determining existing and historical water quality conditions and sediment metals are analyzed at one location each in Rutherford and Colin South Creeks. For Colin Creek South, cadmium, copper, lead, and zinc levels, although below guidelines, were elevated in 2007 relative to other years. Copper, lead, and zinc levels (below sediment guidelines) peaked in 2006 for Rutherford Creek but returned to the range of predevelopment concentrations in 2007. Contaminants are more likely to bind to finer silt particles, and decreased particle sizes of the sampled sediments in Rutherford Creek in 2006 (10.9% total solids) and Colin Creek South in 2007 (23% total solids) correspond with the observed increases

in sediment metals levels. Post-development samples with total solids percentages approximating predevelopment conditions (37.1 to 78.9% in Rutherford Creek, and 72.9 to 83.3% in Colin Creek South) had comparable sediment metals concentrations. Therefore, no corrective actions are recommended.

Groundwater Hydrology

The objective of groundwater hydrology monitoring is to ensure that groundwater recharge is maintained during both the construction phases and following full buildout of the UPDs. Redmond Ridge groundwater hydrology monitoring has been conducted by Associated Earth Sciences, Inc. (AESI) on behalf of Quadrant Corporation since October 1995 at twelve observation wells and one shallow monitoring well. Groundwater levels at Redmond Ridge fluctuate between 0.6 and 3.0 m (2 to 10 ft) in response to precipitation, with a lag time between peak precipitation and peak groundwater levels of 3 to 7 months. Higher than average groundwater levels were observed in the late 1990s and again from 2004 to 2007 in years with higher than average rainfall. The threshold criteria have not been exceeded to date and no corrective actions are recommended.

Trilogy groundwater hydrology monitoring has not been implemented through 2007.

Groundwater Quality

Groundwater quality monitoring is required in the Redmond Ridge monitoring plan to verify that there is no degradation from infiltration facilities of groundwater approaching sensitive receiving bodies (i.e., streams and wetlands) or wells. No groundwater quality monitoring has been implemented through 2007.

Stormwater Facilities

Stormwater facility water level monitoring is required by both the Trilogy and Redmond Ridge monitoring plans to verify stormwater facility performance. Five crest-stage gages and one continuous recorder have been monitored at six Redmond Ridge facilities. None of the stormwater facilities with crest-stage gages have gone into overflow during the monitoring period. Continuous monitoring at ECW1B1 indicates that the peak release rates are exceeding the design targets for the 2-year return storm, but peak flow rates are similar to the predevelopment condition. No corrective actions are recommended until further analysis.

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1.0 INTRODUCTION

Trilogy at Redmond Ridge (formerly Blakely Ridge, and henceforth referred to as 'Trilogy') and Redmond Ridge (formerly Northridge) are adjoining Urban Planned Developments (UPDs) (formerly called Master Planned Developments) located on approximately 2560 acres (1035 hectares) in north central unincorporated King County, Washington (Figure 1). Proposals for development of the Redmond Ridge and Trilogy sites were first submitted to King County in 1984 and 1988 respectively. Following preparation of Environmental Impact Statements (EIS), participation in the Bear Creek Community Plan (BCCP) process, and a series of public hearings, the King County Council approved the Trilogy permit in December 1995 and the Redmond Ridge permit in December 1996. Construction commenced in Redmond Ridge in 1998 and in Trilogy in 1999.

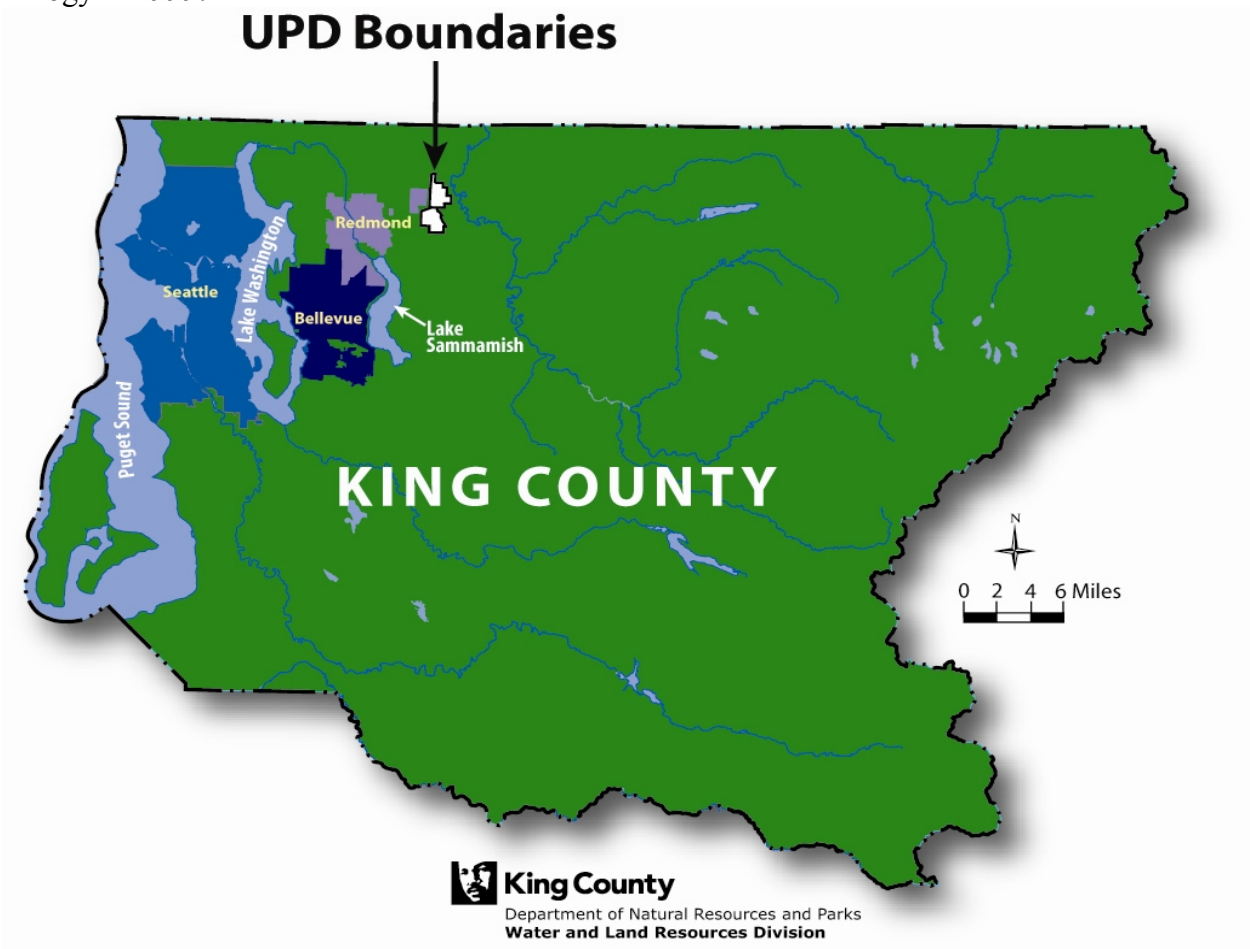

Figure 1. Location of the Trilogy and Redmond Ridge UPDs in north central King County.

The project area contains over 126 wetlands draining to eight headwater streams. Prior to UPD construction, the project area was primarily mature second-growth forest (last logged in 1935-36). To mitigate effects from the construction and development, each project has adhered to a master drainage plan (Northwest Engineering Company 1995, Hugh G. Goldsmith and Associates 1996) retaining 200-ft (60-m) average buffering for all streams and wetlands,

building state of the art retention/detention ponds, and utilizing infiltration to mimic subsurface flow. As a result, over 1100 acres (445 hectares) have been preserved as natural resource buffers and more than 50 stormwater ponds have been constructed.

The Midpoint Report (King County 2006) and the 1998 through 2001 annual reports (Comings et al. 2000, Comings et al. 2001a, b) constitute the reporting through water year 2006. This report presents a brief overview of 2007 water year (i.e., October 1, 2006 through September 30, 2007) construction activities (Section 2), the results from natural resource monitoring (Section 3), and results from stormwater facility performance monitoring (Section 4) including recommendations for corrective actions where appropriate. Presentation of results in Sections 3 and 4 is organized using the following structure for each parameter:
An overview at the beginning of each subsection describes the purpose, schedule, and location of the monitoring activity.

- *Modifications*: describes any changes to the monitoring activity from the original requirements in the Trilogy or Redmond Ridge monitoring plans.
- *Procedures*: briefly outlines the data collection and analysis procedures used.
- *Results*: summarizes key findings for the activity for the 2007 water year.
- *Threshold Exceedance Criteria and Evaluation*: defines and evaluates the results in light of threshold criteria established in the monitoring plans.
- *Corrective Action*: describes any corrective action initiated or recommended to resolve an exceedance or other problem.

The methods and data collected follow recommendations specified in the original Redmond Ridge and Trilogy post-development monitoring plans (King County 1999, 2001). Much of the background information contained in these other documents is omitted in this report. Please refer to the original monitoring plans for more detailed information. In addition, more comprehensive analyses can be found in the midpoint monitoring report (King County 2006) – available online[1] or by request from King County.

The initiation and/or conclusion of the monitoring tasks described in this report relates to 75% buildout[2] of individual subbasins (Figure 2). Across both UPDs construction has surpassed the 75% buildout milestone in all subbasins except BBC[3] (Table 1).

Although Trilogy and Redmond Ridge are two independent developments, many of the monitoring elements are identical or similar. Therefore, the two projects are treated together within this document for reporting simplicity. Recommendations or other elements of the report pertaining to an individual development are emphasized where appropriate.

[1] http://your.kingcounty.gov/dnrp/library/2006/kcr2125.pdf
[2] 75% buildout means that (1) for residential areas 75% of the lots have completed roofs and driveways and (2) for commercial areas 75% of the impervious areas (i.e., buildings and parking lots) have been constructed (King County 1999, 2001). The phased nature of the development makes determination of the buildout status difficult. King County Department of Development and Environmental Services (DDES) uses professional judgment to estimate when conditions meet the 75% buildout criteria for each subbasin.
[3] Throughout this document, subbasins are denoted by their two- or three-letter abbreviation, as described in Table 1.

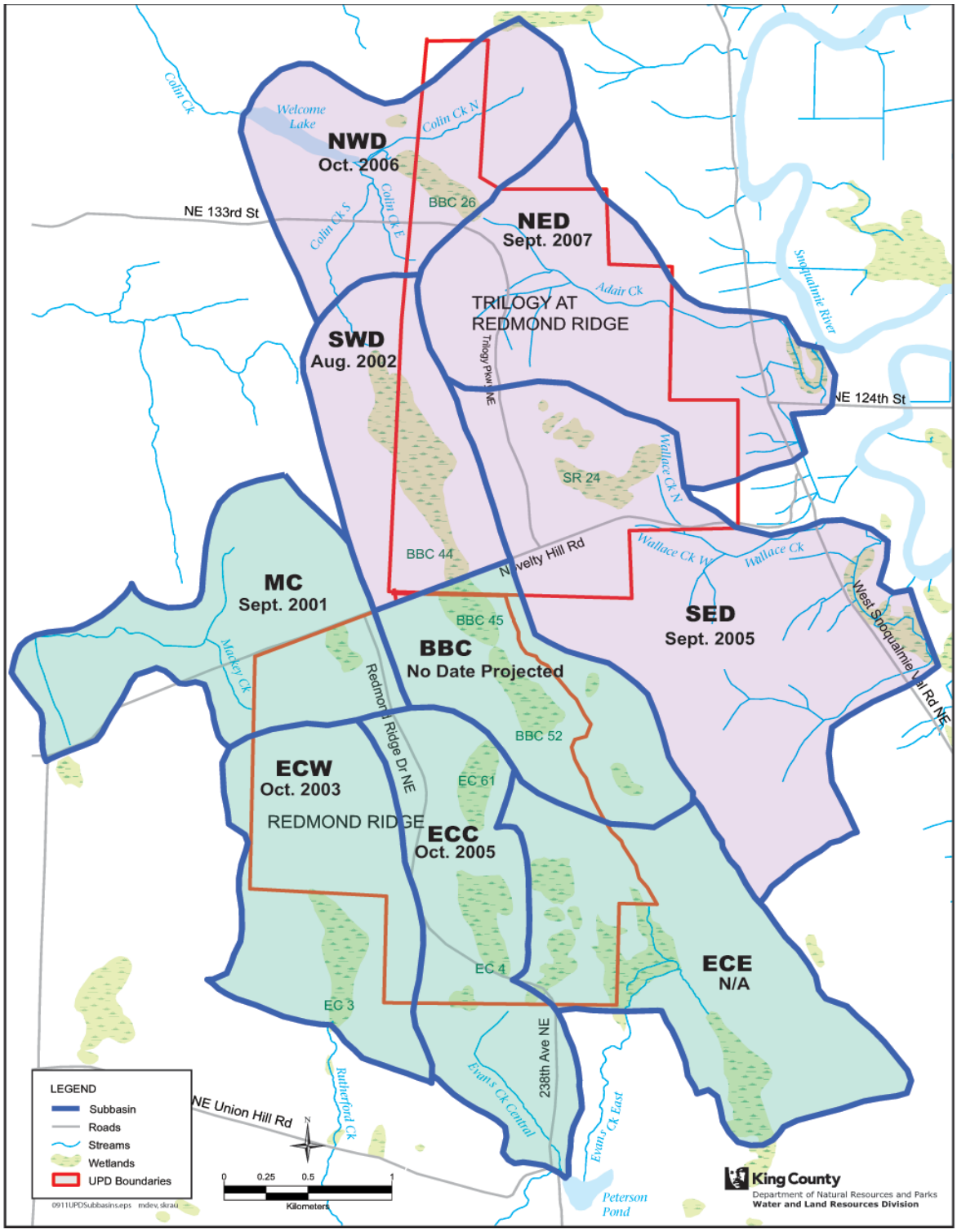

Figure 2. UPD subbasins.

Redmond Ridge (purple) is divided into five drainage subbasins (MC, ECW, BBC, ECC, and ECE) and Trilogy (blue) is divided into four drainage subbasins (NWD, SWD, SED, and NED). See Table 1 for descriptions of the subbasin names. The dates listed represent the month and year where 75% buildout within that subbasin was reached (Lowe 2005, 2008).

Table 1. Development summary by basin.
Status of development and subbasin buildout for the hydrologic basins draining Trilogy and Redmond Ridge at the end of the 2007 water year (Lowe 2005, 2008). Construction generally takes place during the dry season between April 1 and September 30 each year. See Figure 2 for the location of each subbasin.

Subbasin	Construction Start	75% Buildout	Development Complete	Notes
		Trilogy UPD		
Northwest (NWD), Colin Creek North	2003	Oct-06	100%	Final building permit issued September 2007
Northeast (NED), Adair Creek	2002	Sep-07	90%	Some areas of Parcels K, L, M, and N remain
Southwest (SWD), Colin Creek South	2001	Aug-02	> 95%	Only small retail pads remain
Southeast (SED), Wallace Creek[4]	2001	Sep-05	90%	Parts of the Village at Redmond Ridge remain
		Redmond Ridge UPD		
Mackey Creek (MC)	1998	Sep-01	95%	Only one business park parcel remains
Evans Creek West (ECW), Rutherford Creek	1999	Oct-03	100%	
Evans Creek Central[5] (ECC)	2000	Oct-05	90%	Several business park parcels remain
Big Bear Creek (BBC)	2001	No Date Projected	25%	Large portions of the business park remain
Evans Creek East (ECE)	2003	N/A	100%	Very little Redmond Ridge development

1.1 Monitoring Program Goals

A major goal of the UPD monitoring program is to detect and evaluate significant changes to the natural resources that are a result of UPD development, including changes to streams, wetlands, fisheries, and groundwater. The program contains elements for assessing the status of and trends in aquatic macroinvertebrates, amphibians, fish, wetland vegetation, wetland and stream hydrology, stream cross-section stability, water quality, and groundwater quality and quantity (King County 1999, 2001). The data in this report are compared to preconstruction ("baseline") data wherever possible (see Table 1 for construction start dates[6]). In many cases the earliest data available were collected after the first permits were issued and construction was initiated[7]. The initial first phase of construction was limited largely to the Mackey Creek (MC) subbasin in the

[4] The streams draining the Southeast drainage subbasin were formerly referred to as 'Unnamed Creek' in previous reports (Comings et al. 2000, Comings et al. 2001a, b, King County 2006) and the monitoring plans (King County 1999, 2001). However, locally the main creek and its two forks (north and west) are referred to as Wallace Creek and this name is used throughout this report.
[5] The stream draining the Evans Creek Central drainage subbasin has been referred to Evans Middle Fork in previous reports (Comings et al. 2000, Comings et al. 2001a, b). This waterbody is referred to as Evans Creek Central throughout this report.
[6] Mass earth grading construction activity is limited to the days between April 1 and September 30 of each year in an effort to prevent impacts to downstream properties.
[7] The first permits were issued in 1995 for Trilogy and in 1996 for Redmond Ridge. Construction was initiated in 1998 in Redmond Ridge and in 1999 in Trilogy.

northwest portion of Redmond Ridge (KPFF Consulting Engineers 2004), which has no surface connection within the UPDs. Therefore, development impacts to the natural resources are considered to have been negligible, and in some subbasins 1998-99 and other 'post-development monitoring' data are considered baseline data (King County 2006).

The UPD monitoring program also evaluates whether stormwater facilities are working as designed in regard to flow control and water quality objectives. Elements contained in the program include verification of the hydrological and water quality performance of runoff control facilities (King County 1999, 2001). Only hydrological performance has been assessed as of 2007, and these data are also included in this annual report.

1.2 Threshold Exceedance Criteria

The Trilogy and Redmond Ridge monitoring plans identify specific threshold exceedance criteria to ensure the effectiveness of protective actions (King County 1999, 2001). Exceedance of one or more thresholds triggers an investigation into the cause of the exceedance and may require: (1) corrective action to mitigate project-related impacts, should the exceedances be attributable to UPD development, or (2) reconsideration of the threshold. Each threshold criterion is evaluated in this report, and recommendations are provided when exceedances are identified.

2.0 CONSTRUCTION OVERVIEW: WATER YEAR 2007

2.1 Trilogy

Trilogy construction activity in water year 2007 included the M and N subdivisions (NED subbasin), plus Equity Apartments, Cascara Senior Living, and a McDonalds Restaurant (SED subbasin) in the commercial area south of Novelty Hill Road (Figure 3). All four hydrologic basins within Trilogy reached the 75% buildout threshold by September 2007 (Table 1).

2.2 Redmond Ridge

Redmond Ridge construction activity in 2007 was limited to four lots (BP 18, 19, 20, and 24) within the business park (BBC and ECC subbasins) east of Redmond Ridge Drive NE (Figure 3). Three of the four hydrologic basins reached 75% buildout by October 2005 (Table 1). The Bear Creek Subbasin (BBC) is only at 25% buildout with no projected 75% buildout date.

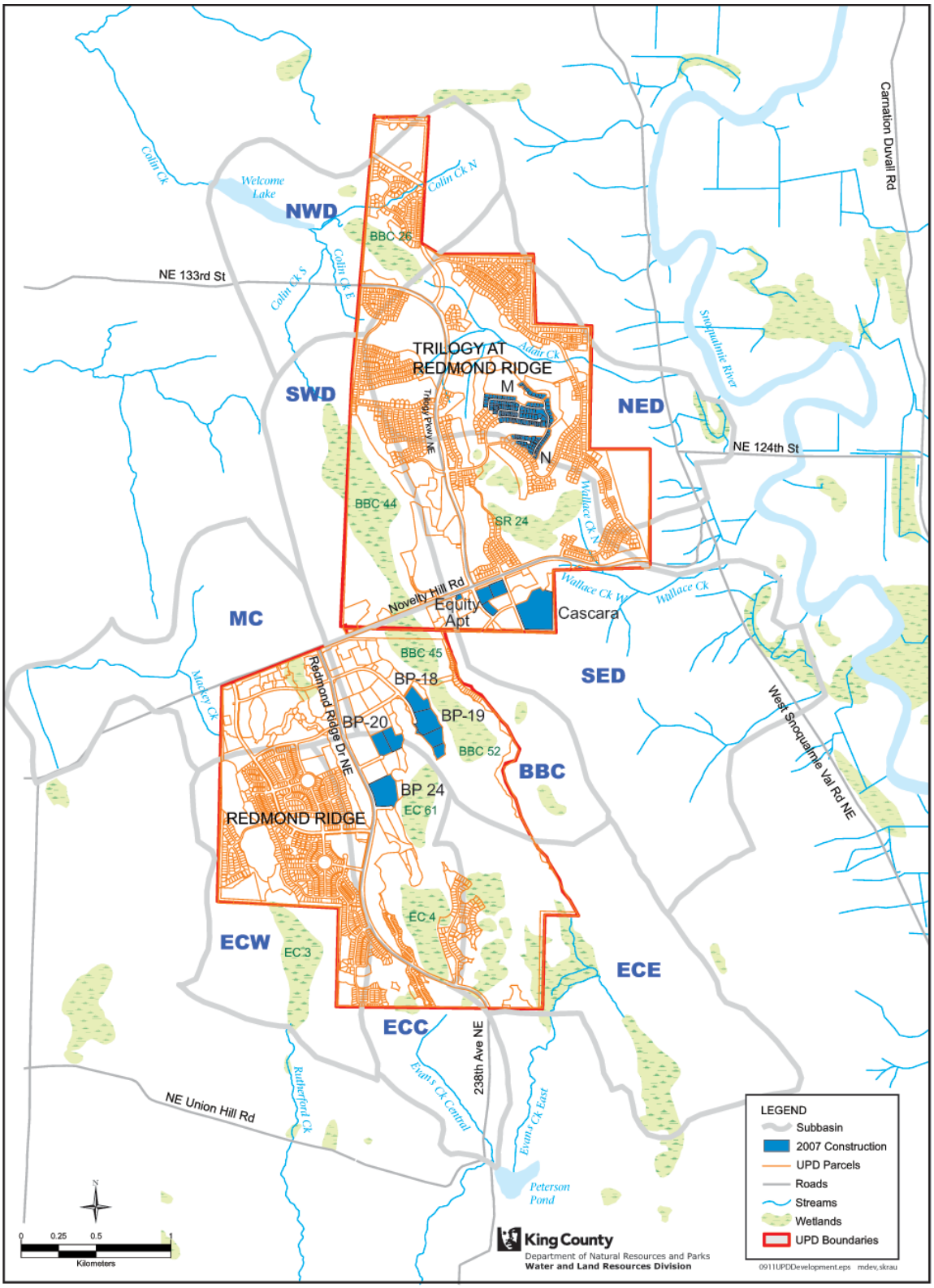

Figure 3. 2007 UPD construction activities.
Construction activities that occurred in 2007 are highlighted in blue on the map and are based on development phasing maps for Trilogy and Redmond Ridge (KPFF Consulting Engineers 2004, Otak Incorporated 2006), 2007 aerial photos, and discussions with UPD engineer Richard Lowe (Lowe 2005, 2008).

3.0 NATURAL RESOURCES MONITORING ACTIVITY

Figure 4 shows all the locations and the type of monitoring required for the UPDs. Between 1998 and 2007 UPD-related monitoring has taken place on or within:

1. Creeks (10): Adair, Colin North, Colin South, Wallace North, Wallace West, Wallace, Mackey, Rutherford, Evans Central, and Evans East Creeks (see Appendix A for alternate names and stream numbers).
2. Wetlands (12): BBC-26, BBC-44, BBC-45, BBC-52, BBC-UN1, EC-61, EC-4, EC-3, SR-24A, SR-24B, SR-24C, and SR-24D[8].
3. Lake: Welcome Lake.
4. Groundwater wells (12): Observation wells OBW-1R, -2R, -3R, -4R, -5, -6, -7R, -8, -10, -11, -12, and monitoring well MW-8.
5. Stormwater facilities (6): BC2-1, ECW3-3, MC1-1, MC2-1, MC4-1, and ECW1B1.

Within the following monitoring sections, parameter-specific maps will highlight the monitoring that took place during the 2007 water year. Monitoring efforts for 2007 are also summarized in Table 2.

[8] Wetland names begin with a two- or three-letter abbreviation that refers to the drainage basin in which they are located. 'BBC' refers to Big Bear Creek; 'EC' refers to Evans Creek, and 'SR' refers to Snoqualmie River.

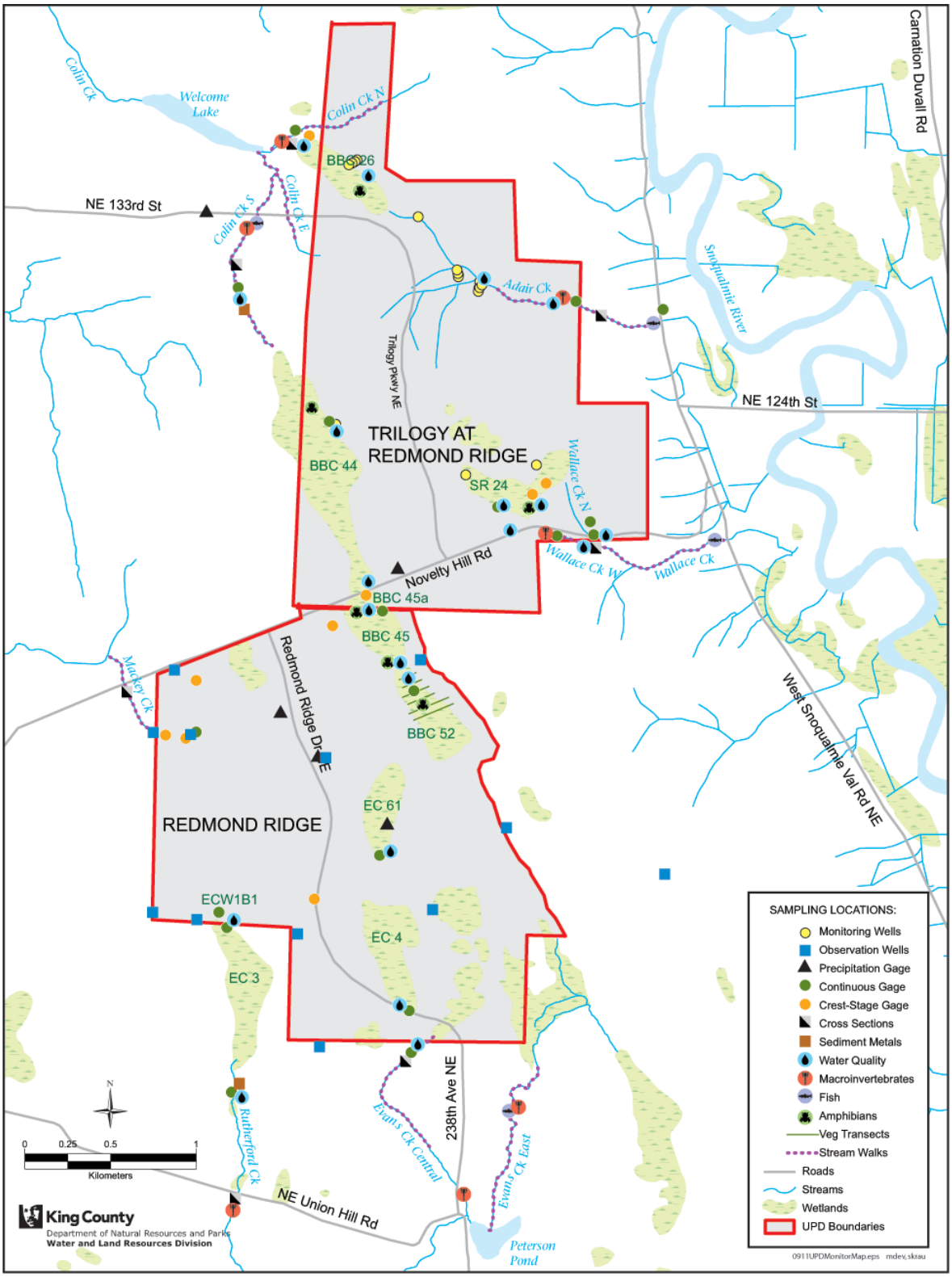

Figure 4. Sampling locations for natural resource monitoring parameters.
Listed parameters are required as part of the Redmond Ridge and Trilogy post-development monitoring plans.

Table 2. 2007 water year monitoring activities.
Natural resource monitoring activities summarized for the 2007 water year at the Trilogy and Redmond Ridge UPDs by subbasin (listed from upstream to downstream).

	Macroinverts	Amphibians	Fish	Gages	Cross-sections	Water Quality	Sediments	Groundwater
Redmond Ridge								
MC: Mackey Creek								
Stormwater ponds MC: 2-1, 1-1, 4-1				X				
Groundwater wells								X
ECW: Evans Creek West (Rutherford)								
EC-3				X				
Rutherford Creek (18F)				X			X	
Stormwater ponds ECW: 1B1, 3-3				X				
Groundwater wells								X
ECC: Evans Creek Central								
EC-61				X		X		
EC-4				X		X		
Evans Creek Central (18B)				X		X		
Groundwater wells								X
ECE: Evans Creek East								
Evans Creek East								X
BBC: Big Bear Creek								
BBC-52		X		X		X		
BBC-45		X (2)		X		X (2)		
BBC-UN1				X				
Stormwater pond BC2-1				X				
Groundwater wells								X
Trilogy								
SWD: Southwest Drainage (Colin South)								
BBC-44		X		X				
Colin Creek South (02D)				X		X	X	
Welcome Lake				X		X		
Precipitation (02V)				X				
NWD: Northwest Drainage (Colin North)								
BBC-26		X		X		X (2)		
Colin Creek North (02C)				X				
NED: Northeast Drainage (Adair)								
ADCW1				X		X		
Adair Creek(53A or 53A u/s)	X		X	X	X	X		
Adair Creek Bypass (53D)				X				
SED: Southeast Drainage (Wallace)								
SR-24A				X		X		
SR-24B				X		X		
SR-24C		X		X		X		
Wallace Creek North (53C)				X		X		
Wallace Creek West (53B)	X			X		X		
Wallace Creek Bypass (53F)				X				

3.1 Precipitation

Because most hydrologic processes are closely linked to the timing, intensity, and duration of rainfall in a watershed, precipitation monitoring provides context for considering how 2007 data should be interpreted. Precipitation has been monitored continuously by the King County Water and Land Resources Division (WLRD) since May 1995[9] at Station 02V located 2,000 ft (610 m) west of the Trilogy UPD on NE 133rd Street (Figure 5). The locations of four other precipitation gages, three of which are no longer in place, are also shown on the map. Data are to be reported annually until the cessation of all reporting activities associated with UPD monitoring required by the Trilogy and Redmond Ridge monitoring plans.

[9] Gage 02V was initially installed in 1989 for UPD preconstruction monitoring. It was removed in 1993. The gage was re-established in May 1995 at a nearby location, which has been maintained to date.

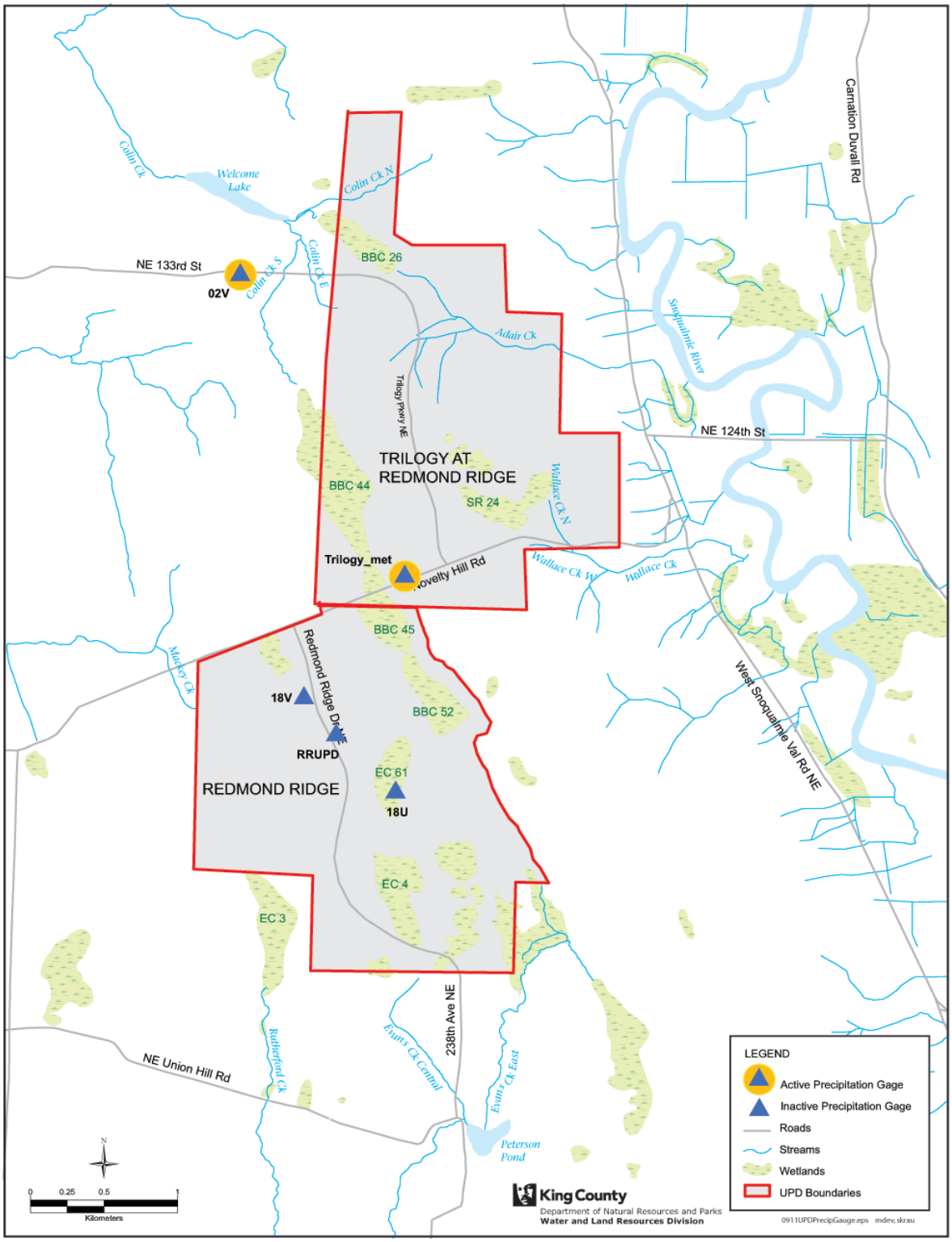

Figure 5. Location of five UPD-related precipitation gages.
02V and Trilogy_met are active. 18u, 18v, and RRUPD provide historical data, but the gages have been removed[10].

[10] Active dates for 5 UPD precipitation gages: 02V 10/1/94 to present; 18U 12/1/87 to 10/1/00; 18V 1/1/99 to 2/1/05; RRUPD 7/22/02 to 10/17/05; and Trilogy_met 5/31/05 to present.

Modifications

No modifications to the precipitation monitoring activities have occurred.

Sampling recommendations – Continue monitoring Station 02V until all Trilogy and Redmond Ridge UPD monitoring is complete.

Procedures

Monitoring data from Station 02V are obtained from the King County Hydrologic Information Center web page (link[11]). The rain gage uses a tipping bucket gage and 8-inch (20.3 cm) diameter funnel to measure rainfall. An electronic data logger records rainfall every 15 minutes in 0.01 inch (0.02 cm) increments and stores the gage output. Data are uploaded, the logger maintained, and the rain gage calibration checked approximately 10 times a year. Data accuracy is verified by comparing nearby gage records for anomalies. Where equipment failure produces a gap in the record, rainfall is estimated from nearby recording gages and volunteer observations. Quality controlled data are then exported to the Hydrologic Information Center web page.

Results

Daily and cumulative precipitation totals for water year 2007 are presented graphically in Figure 6. Tabular data summaries of daily and monthly precipitation totals shown in Table 3 present average monthly precipitation totals measured at Station 02V from October 1995 through September 2007 to provide historical context.

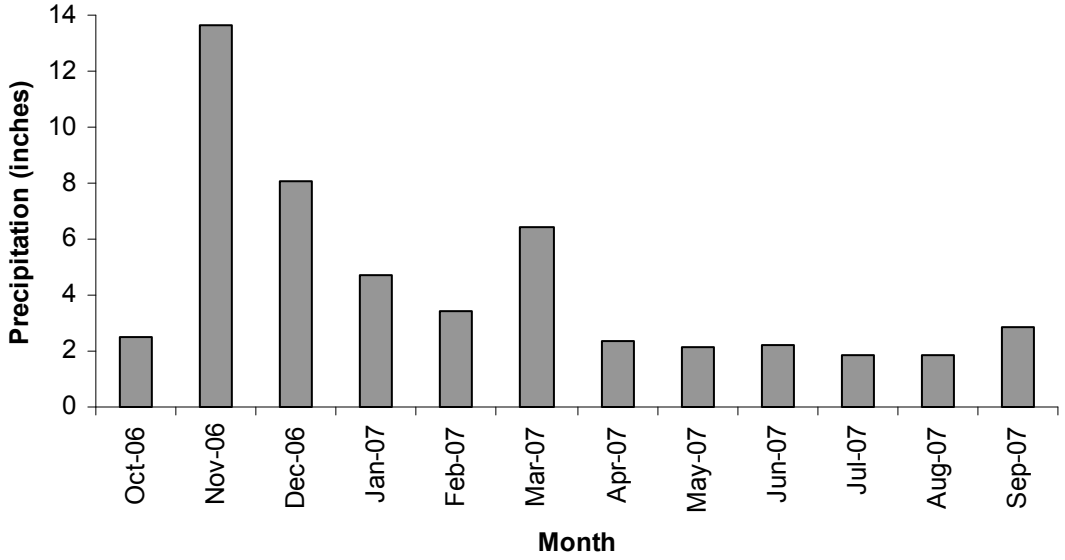

Figure 6. Cumulative monthly precipitation for water year 2007 at Station 02V in Trilogy.

[11] http://green.kingcounty.gov/WLR/Waterres/hydrology/

Table 3. Daily and monthly precipitation totals in inches for water year 2007.

	Water Year 2007											
Day	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
1	0.00	0.01	0.06	0.25	0.00	0.10	0.11	0.09	0.00	0.00	0.00	0.00
2	0.00	0.89	0.01	0.87	0.00	0.73	0.09	0.34	0.00	0.00	0.00	0.00
3	0.00	0.70	0.01	0.33	0.11	0.23	0.00	0.01	0.04	0.00	0.23	0.00
4	0.00	1.03	0.01	0.12	0.05	0.01	0.00	0.35	0.01	0.00	0.00	0.54
5	0.00	0.40	0.00	0.43	0.00	0.04	0.00	0.01	0.30	0.00	0.00	0.00
6	0.06	1.50	0.00	0.12	0.07	0.00	0.00	0.01	0.06	0.00	0.00	0.00
7	0.01	1.23	0.00	0.65	0.12	0.23	0.03	0.01	0.19	0.00	0.00	0.00
8	0.00	0.25	0.02	0.07	0.05	0.48	0.22	0.00	0.00	0.00	0.16	0.00
9	0.00	0.42	0.20	0.44	0.04	0.06	0.22	0.00	0.41	0.00	0.00	0.00
10	0.00	1.04	0.19	0.01	0.06	0.11	0.01	0.00	0.01	0.00	0.00	0.00
11	0.00	0.05	1.05	0.01	0.23	0.68	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.85	0.50	0.00	0.01	0.10	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.30	0.30	0.00	0.06	0.00	0.16	0.00	0.00	0.01	0.00	0.00
14	0.02	0.05	1.67	0.00	0.16	0.06	0.24	0.00	0.05	0.00	0.00	0.00
15	0.59	0.84	0.10	0.00	0.34	0.10	0.29	0.00	0.22	0.00	0.00	0.00
16	0.15	0.21	0.01	0.00	0.04	0.01	0.04	0.00	0.06	0.00	0.00	0.15
17	0.00	0.00	0.00	0.12	0.08	0.32	0.01	0.00	0.25	0.01	0.00	0.36
18	0.38	0.00	0.00	1.01	0.00	0.03	0.52	0.04	0.08	0.22	0.17	0.01
19	0.45	0.39	0.08	0.18	0.58	0.46	0.00	0.01	0.00	0.03	0.62	0.00
20	0.01	0.60	0.10	0.01	0.26	0.44	0.00	0.67	0.00	0.39	0.26	0.00
21	0.00	0.90	0.66	0.00	0.00	0.00	0.01	0.32	0.00	0.26	0.00	0.03
22	0.01	0.61	0.00	0.00	0.13	0.37	0.05	0.02	0.00	0.74	0.00	0.17
23	0.00	0.30	0.45	0.06	0.03	0.27	0.00	0.00	0.00	0.11	0.00	0.00
24	0.42	0.00	0.88	0.00	0.33	0.70	0.09	0.00	0.12	0.00	0.00	0.01
25	0.00	0.07	0.09	0.03	0.11	0.16	0.02	0.00	0.01	0.00	0.11	0.01
26	0.00	0.46	0.91	0.00	0.14	0.03	0.06	0.00	0.00	0.00	0.28	0.00
27	0.01	0.02	0.45	0.01	0.07	0.39	0.00	0.23	0.00	0.00	0.00	0.33
28	0.00	0.00	0.03	0.01	0.34	0.00	0.03	0.00	0.26	0.00	0.00	0.19
29	0.35	0.00	0.30	0.00		0.00	0.00	0.00	0.16	0.11	0.00	0.17
30	0.01	0.55	0.01	0.01		0.04	0.17	0.00	0.00	0.00	0.00	0.88
31	0.00		0.00	0.01		0.25		0.00		0.00	0.00	
Max. daily total	0.59	1.50	1.67	1.01	0.58	0.73	0.52	0.67	0.41	0.74	0.62	0.88
Monthly total	2.47	13.67	8.09	4.75	3.41	6.40	2.37	2.11	2.23	1.88	1.83	2.85
Hist. monthly total [a]	4.67	6.69	5.78	6.11	3.88	4.02	3.29	3.11	1.86	0.82	1.18	2.09

[a] Historical average monthly precipitation totals measured at rain gage 02V from October 1995 through September 2006

At 52.06 inches (132.2 cm), water year 2007 was the third wettest year on record for Station 02V (Figure 7). Total precipitation was 30.3% above the October 1995 to September 2007 average of 43.49 inches (110.5 cm). Water year 2007 also saw the highest monthly rainfall recorded at the gage (November 2006, 13.67 inches (34.7 cm) [Table 3]). The maximum daily precipitation during water year 2007 was 1.67 inches (4.2 cm) (December 14, 2006).

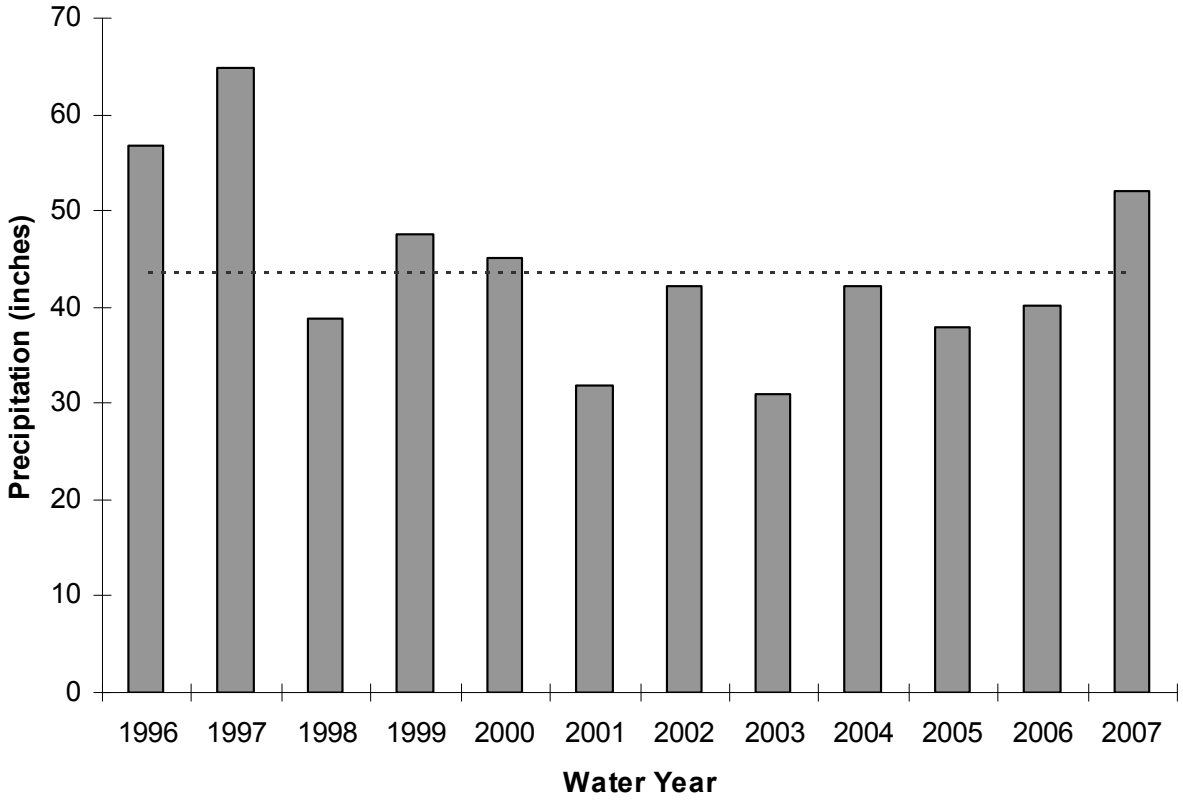

Figure 7. Cumulative annual precipitation in inches from water year 1996 through 2007.
The horizontal line represents the mean annual precipitation from 1996-2007.

Threshold Exceedance Criteria

There are no threshold criteria associated with precipitation monitoring.

Corrective Actions

No corrective actions are recommended for this monitoring element.

3.2 Macroinvertebrates

Freshwater benthic macroinvertebrates are animals without backbones larger than 0.5-mm and visible without a microscope that are primarily bottom dwellers in freshwater habitats. Benthic macroinvertebrates are key components of lotic ecosystems[12] and provide a functional link between organic matter and fish in aquatic food webs. Analyses of the benthos can provide information reflective of habitat quality, overlying water quality, and potential food resources present. As such, benthic macroinvertebrates are excellent indicators of general stream conditions. They are routinely used in biomonitoring programs because of their high abundance and diversity, limited migration patterns, response to environmental disturbances, and natural population structure that is unaltered by stocking or harvesting.

[12] Lotic refers to moving waters such as streams or rivers.

Benthic macroinvertebrate sampling has been conducted at seven creeks draining the Trilogy and Redmond Ridge UPDs (Rutherford, Evans Central, Evans East, Adair, Wallace, Colin North, and Colin South Creeks) (Figure 8) in 1999, 2000, 2001, and 2006. Beginning in 2007, sampling was spaced at 1, 3, and 5 year intervals relative to 75% buildout. In 2007, macroinvertebrates were only collected at Adair and Wallace Creeks[13]. See Appendix B for details of past sampling schedules.

[13] 2007 macroinvertebrate sampling should have taken place in Adair and Colin North, but Wallace was sampled by mistake instead of Colin North.

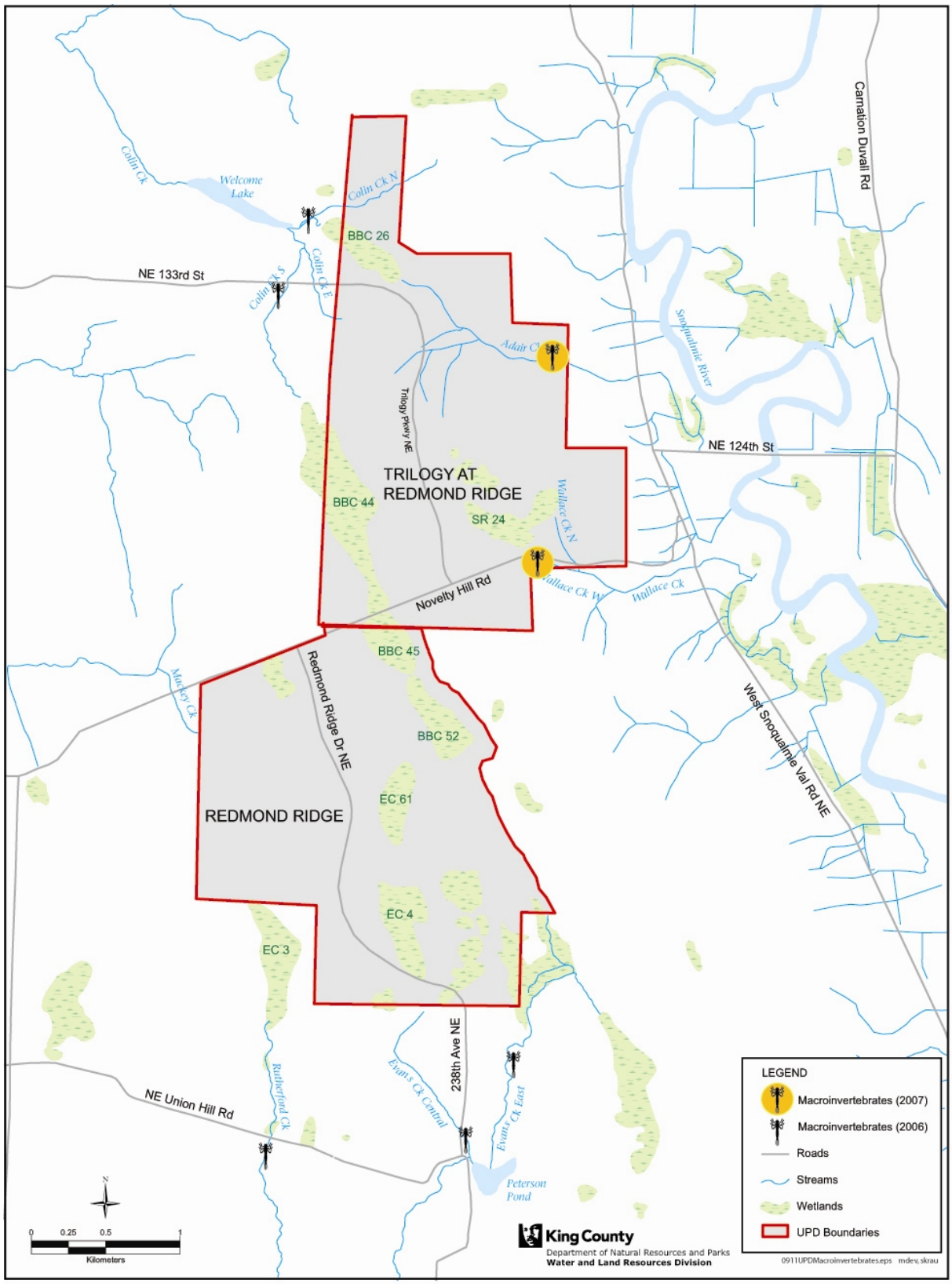

Figure 8. Location of seven UPD benthic macroinvertebrate monitoring stations.
Adair and Wallace Creeks were sampled in 2007.

Modifications

The Redmond Ridge monitoring plan (King County 1999) calls for annual benthic macroinvertebrate sampling beginning in the first year of construction until six years following 75% buildout at Rutherford and Evans Central Creeks. The Trilogy monitoring plan (King County 2001) calls for annual or spaced (1, 3, 5 year following 75% subbasin buildout)[14] benthic macroinvertebrate sampling beginning at construction and resuming following 75% subbasin buildout at Adair, Wallace West, Colin North, and Colin South Creeks. None of the sites were sampled in June of 2002-2005 despite the onset of construction in all basins and 75% buildout triggers in Rutherford (Oct. 2003) and Colin South (Aug. 2002) Creeks. Evans Creek East, which was not identified in either plan, has been routinely monitored in addition to the six sites specified in the monitoring plans (Figure 8). Beginning in 2007, all benthic macroinvertebrate sampling was shifted to a 1, 3, 5 year following 75% subbasin buildout schedule.

Sampling recommendations – Proceed with spring sampling at the seven streams on a modified schedule based on 1, 3, and 5 year post-75% buildout sampling.

Procedures

Macroinvertebrates are collected between late May and mid June of each year following the recommended sampling protocols outlined by Karr and Chu (1999). At each location, a Surber sampler (500 µm mesh, 1 ft^2 [0.3 m^2] frame) is used to collect three replicate samples along the midline of a single riffle starting first with the downstream end, then the middle, and finally near the upstream end of the riffle. All large material (e.g., large gravel, cobble, and woody debris) within the sampling area is scrubbed by hand and examined before being placed outside of the Surber frame. A sturdy metal gardening hand tool is used to agitate the substrate within the perimeter of the frame to a depth of approximately 10 cm (3.9 in) for 60 seconds. Each sample collected is processed and condensed separately without compositing before being transferred to a sample container and preserved in the field with 95-100% ethanol (EtOH).

After field data collection each year, all samples are sent to a taxonomic laboratory for identification to the lowest possible taxonomic resolution[15]. Non-insect invertebrates (e.g., worms) are identified to family, order, or class. Each replicate is subsampled at 500 organisms, but if fewer than 500 organisms are present, which is often the case, the entire sample is processed. Taxonomic data are uploaded to the Puget Sound Stream Benthos web page (link[16]).

Macroinvertebrates are classified by habit (e.g., clinger) based on Merritt and Cummins (1996), and by pollution tolerance, long-lived status, and predator status based on the unpublished list provided in 1998 by Robert Wisseman, Senior Scientist of Aquatic Biology Associates, Inc.

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[14] The Trilogy Monitoring does not specify criteria to determine whether sampling follows the annual or spaced sampling schedule. The 1, 3, and 5 years following 75% buildout allows potential effects to be captured over a longer time period, but the schedule decision is left up to the discretion of WLRD scientists.

[15] Exceptions to the lowest possible taxonomic resolution include identifying organisms to sub-family for Ceratopogoniae (biting midges) and to family level for Chironomidae (midges), Dolichopodidae (aquatic long legged flies), Dytiscidae (predaceous diving beetles), and Sciomyzidae (marsh flies). Capnidae (slender winter stoneflies), Leuctridae (rolled winged stoneflies), and Odonata (dragonflies and damselflies), were identified to family or order through 2000, but have been identified to genus in subsequent years. 1999 and 2000 taxa were never identified below genus level.

[16] http://www.pugetsoundstreambenthos.org/

These attributes are used to calculate the ten metrics that make up the Puget Lowland Benthic Index of Biotic Integrity (BIBI). The scores from the ten metrics are summed to provide an overall BIBI score ranging from 10 to 50 for each of the three replicates. The three replicate BIBI scores are then averaged for each site for a single overall BIBI score.

Results

Taxonomic data are presented in Appendix C and BIBI scores are presented in Table 4. Two streams were sampled in 2007: Adair and Wallace West Creeks, with BIBI scores of 33.3 and 30.7, respectively, which fall into the 'fair' category for biological condition (Appendix D). The average sample size for the three samples at each creek was well below 300 organisms, which is considered the minimum sample size for BIBI calculations (Adair Creek: 82, 69, and 208; Wallace Creek West: 75, 105, and 202 organisms in each sample).

Table 4. BIBI Scores for Adair and Wallace West Creeks.
1999-2001 was preconstruction at all sites. 2006 was during construction at Adair Creek and post-75% buildout for Wallace Creek West. 2007 was post-75% buildout for both sites.

Site Code	1999	2000	2001	2006	2007
Adair Creek	30.0	35.3	42.7	32.7	33.3
Wallace Creek West	29.3	34.7	28.0	25.3	30.7

Threshold Exceedance Criteria and Evaluation

Benthic macroinvertebrate threshold exceedance criteria are violated if there is a 20% or more decline in BIBI scores (King County 1999)[17]. Baseline years for BIBI in the UPDs are considered to be 1999, 2000, and 2001, because they all are preconstruction. On Adair Creek, the BIBI baseline scores ranged from 30 in 1999 to 42.7 in 2001; on Wallace Creek West, the BIBI baseline scores ranged from 28 in 2001 to 34.7 in 2000. The 2007 BIBI scores for Adair Creek (32.0) and Wallace Creek West (30.7) are within the predevelopment baseline range and therefore the threshold criteria were not exceeded.

The very low numbers of organisms collected in both streams in 2007 calls into question the appropriateness of BIBI calculations at these locations (Table 5). Adair Creek dropped from an average of nearly 390 invertebrates per replicate during the baseline years to under 120 in the post-development years. Similarly, Wallace Creek dropped from over 625 invertebrates per sample to under 224. In 1999 and 2000, all organisms found in a sample were counted and in subsequent years they have been subsampled at 500 organisms. However, this sample processing change does not explain all the variation because 500 organisms have been exceeded in only one replicate in 2006 or 2007. Because the BIBI relies on several richness metrics (e.g., taxonomic, mayfly, stonefly, and caddisfly richness), BIBI scores might increase when more organisms are counted. However, despite the reduced abundances, the 2007 BIBI scores are still within the range of scores observed during the predevelopment years.

[17] The Redmond Ridge monitoring plan (King County 1999) uses the BIBI threshold exceedance criteria, whereas the Trilogy monitoring plan (King County 2001) refers to a 20% decline in macroinvertebrate communities compared to baseline. Because BIBI is a measure of community composition, it was chosen for threshold exceedance criteria for all macroinvertebrate data regardless of which UPD they drain.

Table 5. Benthic macroinvertebrate abundance for Adair and Wallace Creeks.
Three time periods are calculated including: predevelopment (1999-2001 Adair Creek , 1999-2000 Wallace Creek West) construction (2006 Adair Creek, 2001 Wallace Creek West), and post-development (2007 Adair Creek, 2006-2007 Wallace Creek West). Post-development is after 75% buildout in each subbasin. N is sample size.

	Predevelopment					Construction					Post-development				
	n	Avg	StDev	Min	Max	n	Avg	StDev	Min	Max	n	Avg	StDev	Min	Max
Adair	9	389.1	243.4	161	882	3	95.7	78.5	31	183	3	119.7	76.8	69	208
Wallace	6	751.0	227.3	502	1139	3	375.0	103.6	289	490	6	223.5	128.2	75	427

Corrective Actions

No corrective actions are recommended for this component of the monitoring plan.

3.3 Amphibians

In King County, a wide array of amphibians utilize wetlands during some life stage, with eight native species breeding in lentic habitats[18] (Richter and Azous 2001). Urbanization has been demonstrated to impact wetlands in numerous direct and indirect ways that result in habitat loss, hydrologic changes (Reinelt and Taylor 2001), altered water quality (Horner et al. 2001b), and lagged declines in biodiversity (Findlay and Josée 2000). Monitoring breeding amphibian populations may provide early warning signs regarding wetland habitat, hydrologic changes, and water quality deterioration, because amphibians are considered sensitive indicators of changes in water regimes, sedimentation, and water quality (Reinelt et al. 1998, Richter et al. 1998, Richter and Azous 2001).

Amphibian egg mass surveys have been conducted twice each spring in six locations on five wetlands (Figure 9) beginning in 2000 (BBC-52, BBC-45 d/s & u/s, SR-24C), 2001 (BBC-44), or 2002 (BBC-26) and will continue for three (BBC-44, BBC-26, SR-24C) or four (BBC-52, BBC-45) years following 75% buildout in each subbasin. See Appendix E for details of the sampling schedule through 2007.

[18] Lentic refers to still waters such as lakes and ponds.

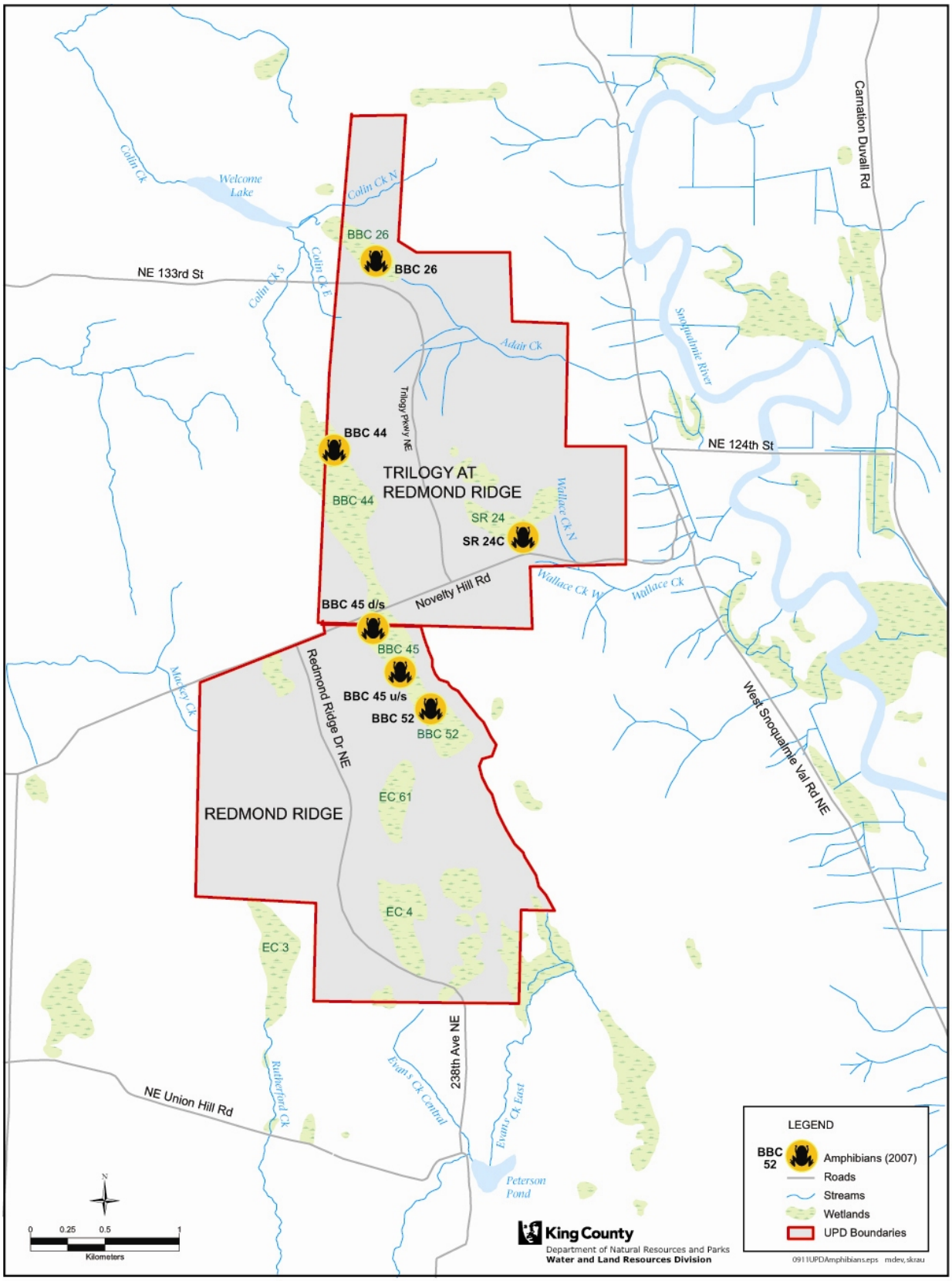

Figure 9. Location of amphibian breeding surveys.
Amphibian breeding surveys were conducted at all six sampling locations on five wetlands in 2007.

Modifications

The Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) call for sampling one location at SR-24C, BBC-26, BBC-44, and BBC-52 and two locations at BBC-45 (d/s and u/s)[19]. Both monitoring plans call for sampling three times each spring. However, this effort was reduced to twice each spring to focus on capturing the primary breeding period for the region's native lentic-breeding amphibians. The third sampling period from early May to mid June was intended to capture breeding activity for non-native bullfrogs (*Rana catesbeiana*) and native Western Toads (*Bufo boreas*), but no monitoring has ever been conducted during this time frame.

Sampling recommendations – Proceed with the twice annual sampling protocol at five sites on four wetlands. BBC-44 has met the monitoring duration requirements and will no longer be sampled.

Procedures

Amphibian breeding surveys generally follow methods outlined by Thoms et al. (1997) modified by Richter and Ostergaard (1999). Two annual egg mass surveys are conducted by two biologists in the first three weeks of March and the second two weeks of April. Throughout the UPD monitoring efforts, these surveys vary slightly from year to year based on the timing of oviposition. Rain, high winds, and overcast conditions are avoided whenever possible to maximize visibility through the water column. Surveys are conducted in the wetlands by wading in shallow water or floating in a small float tube in water deeper than 3.3 ft (1 m). Egg masses are identified by species and percent mortality per clutch estimated within eight categories (0%, 1-5%, 6-25%, 26-50%, 51-75%, 76-95%, 96-100%, or partially hatched). Larvae, paedomorphs[20], juveniles, and adults are also identified to species if possible, and calling frogs are noted and identified by call when heard.

Results

Amphibian richness

Egg masses of four native species were commonly found during the monitoring periods at the five surveyed wetlands. These included Northwestern salamanders (*Ambystoma gracile*), Northern red-legged frogs (*Rana aurora*), Pacific tree frogs (*Pseudacris regilla*), and long-toed salamanders (*Ambystoma macrodactylum*) (Figure 10). Non-native American bullfrogs (*Rana catesbeiana*) were documented at all amphibian breeding survey locations except BBC-45d/s and BBC-45u/s based on visual observations of living or dead adults (BBC-44, BBC-26, and SR-24C) or living larvae (BBC-52). Rough-skinned newts (*Taricha granulosa*) were noted infrequently. Survey results can be used to determine species presence, but failure to see a species does not ensure its absence especially for long-toed salamanders, which have eggs that are difficult to find and active periods that are before our survey period.

[19] The two BBC-45 locations are referred to as BBC-45d/s and BBC-45u/s. D/s refers to 'downstream' and u/s refers to 'upstream'.
[20] Paedomorphs retain larval characteristics (such as the retention of gills) into adult life (Jones et al. 2005).

Species richness varied across the years with increases and decreases in all the surveyed wetlands (Figure 10). There are no obvious increasing or decreasing trends over time regardless of construction and development in the basins.

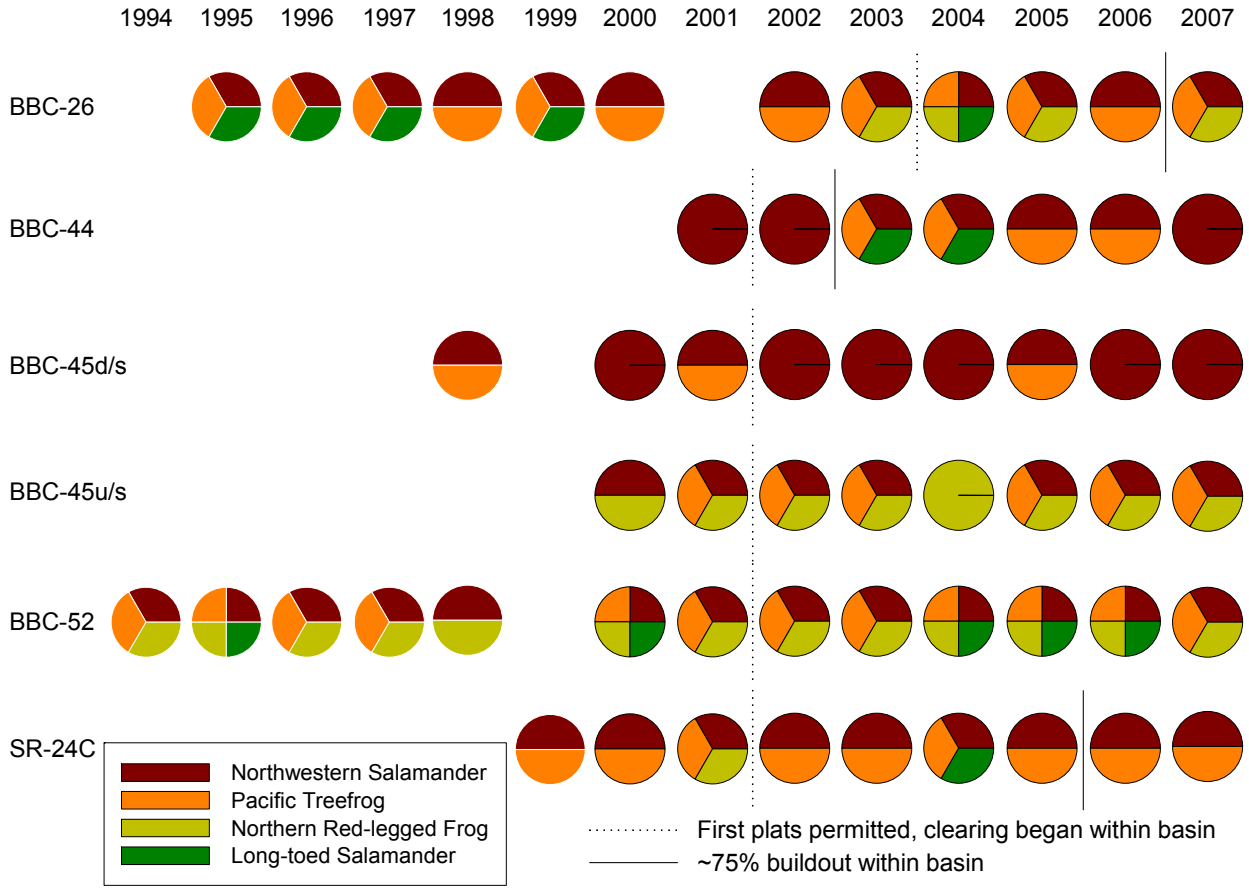

Figure 10. Species composition of amphibian egg masses at various UPD wetland sites.
The proportion of the pie assigned to each species is based on the species richness and is not representative of abundance. The pies sub-divided by white lines (1994-1999 & BBC-26 2000) represent data collected by volunteers and in all cases except for BBC-45d/s these data were collected at a different location from subsequent staff-conducted surveys. Permit and clearing start dates were estimated from development phasing maps (KPFF Consulting Engineers 2004, Otak Incorporated 2006) combined with aerial photos (1998, 2000, 2002, 2005, 2007). 75% buildout dates were estimated by Richard Lowe (2005, 2008).[21]

Egg mass abundance

Egg mass abundances for wetland-breeding amphibians are shown for all six wetland locations from 2000 to 2007 in Table 6. Long-toed salamander egg mass abundances are generally less than 5 per year with a peak of 15 at BBC-52 in 2004. No long-toed salamander egg masses were observed in 2007. Pacific treefrog and northern-red legged frog egg masses are most commonly

[21] In the Midpoint Report (King County 2006), a similar figure presented species richness for adults, larval, and egg stage. This figure only presents the species richness for egg masses within each surveyed wetland. In addition, analysis of aerial imagery reveals that some development took place after the 2001 breeding season in the BBC-45 and BBC-52 basins. The clearing lines have been adjusted accordingly.

observed in BBC-52. This trend continued in 2007 with 456 Pacific treefrog and 48 northern red-legged frog egg masses in BBC-52 and 6 or fewer of either species at the other five sites. Pacific treefrog egg mass abundances within BBC-45u/s generally declined from a high of 16 egg masses in 2001 to 1 egg mass in 2006, but the consistently low levels may suggest that this location was never optimal Pacific treefrog breeding habitat. Northwestern salamander egg masses are the most commonly observed egg mass at the UPD wetlands with more than 100 northwestern salamander egg masses generally observed annually in BBC-26, BBC-44, and SR-24C (exceptions include 57 in BBC-44 in 2005 and 91 in SR-24C in 2000). In 2007, Northwestern salamander egg masses reached an all time high in BBC-26 (610) and BBC-44 (215) and rebounded from relatively low 2006 abundances in BBC-52 (66 to 108) and SR-24C (146 to 190).

Table 6. Amphibian egg mass abundance from 2000 to 2007.
Two surveys were conducted each year and these numbers represent the maximum number of egg masses observed for four amphibian species between the two surveys.

	Long-toed Salamander								Pacific Treefrog							
	'00	'01	'02	'03	'04	'05	'06	'07	'00	'01	'02	'03	'04	'05	'06	'07
BBC-26			0	0	4	0	0	0			9	10	22	43	19	6
BBC-44		0	0	2	2	0	0	0		0	0	2	1	8	3	0
BBC-45d/s	0	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0
BBC-45u/s	0	0	0	0	0	0	0	0	0	16	14	11	0	4	1	5
BBC-52	3	0	0	0	15	1	5	0	51	190	89	559	74	50	152	456
SR-24C	0	0	0	0	5	0	0	0	41	82	15	20	11	12	4	6

	Northern Red-legged Frog								Northwestern Salamander							
	'00	'01	'02	'03	'04	'05	'06	'07	'00	'01	'02	'03	'04	'05	'06	'07
BBC-26			0	2	3	4	0	6			329	233	214	268	358	610
BBC-44		0	0	0	0	0	0	0		149	202	169	175	57	211	215
BBC-45d/s	0	0	0	0	0	0	0	0	19	42	80	46	39	42	87	76
BBC-45u/s	10	3	2	2	1	2	1	3	7	2	20	3	0	5	10	13
BBC-52	21	13	25	40	89	42	42	48	86	36	103	33	70	19	66	108
SR-24C	0	1	0	0	0	0	0	0	91	207	265	282	257	293	146	190

Egg mass mortality

Mean egg mass mortalities[22] are calculated for Northwestern salamanders, Pacific treefrogs, and Northern red-legged frogs for each wetland survey period by averaging the midpoint of each percent mortality category (0%, 1-5%, 6-25%, 26-50%, 51-75%, 76-95%, 96-100%). No long-toed salamander egg masses were observed in 2007 and they were omitted from the mortality evaluation. Mean egg mass mortality was usually less than the threshold exceedance criteria of 20% regardless of species or wetland location (Figure11). Exceptions include Pacific treefrog egg mass mortality in BBC-45u/s in 2005 (24.5%) and in BBC-52 in 2006 (22.9%). Northwestern salamander egg mass mortality has exceeded 20% in SR-24C in 2000 (27.6%) and repeatedly in BBC-45d/s in all but three of the surveyed years: 2001 (35.7%), 2002 (52.8%), 2005 (27.6%), 2006 (54.3%), and 2007 (67.3%).

[22] Mortality estimates are categorical and subjective. It is sometimes difficult to see actual egg masses because of turbid conditions or thick algal growth within the egg mass. Judging which category to put the mortality estimation in is up to best professional judgment, which may vary by observer.

Pacific treefrog egg mass mortality in BBC-52 dropped to 18.1 and 2.9% in the 1st and 2nd 2007 survey periods, respectively. Egg mass mortalities in previous years may have been a result of water level fluctuations (in 2005 four Pacific treefrog egg masses were observed partially stranded above the water surface) or wetland freezing (which was extensive in 2006).

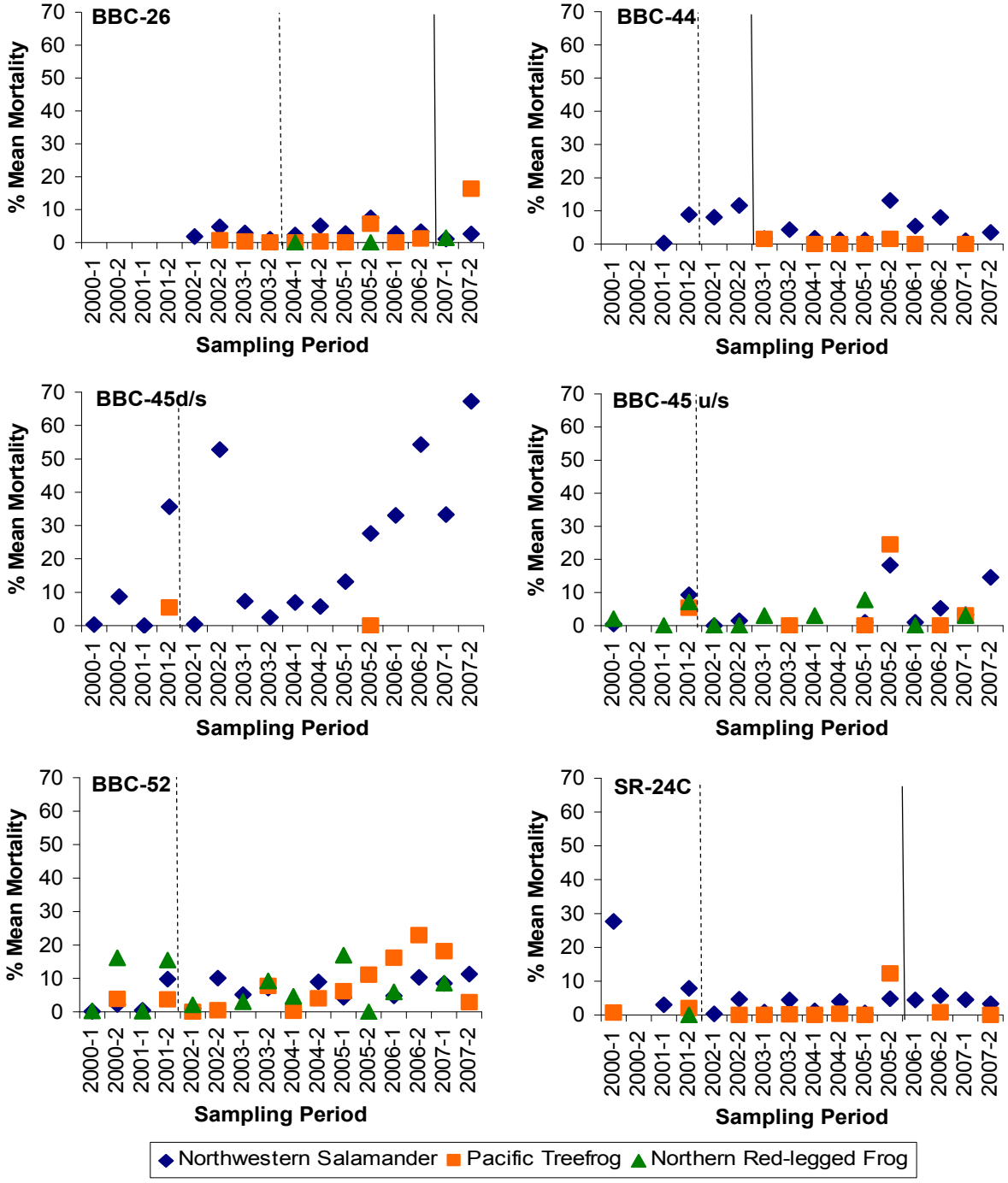

Figure 11. Amphibian egg mass mortality.
Mean mortality was calculated by averaging the midpoint of each category. The resulting number is only an approximation of mortality because these data were categorical. Each year is divided into the two survey periods (e.g., 2000-1 and 2000-2).

UPD clearing in the BBC subbasin began in 2001 but was limited to a road circuit and three stormwater facilities. More extensive clearing and development began within the BBC subbasin in April 2005, therefore the high levels of Northwestern salamander egg mass mortalities at BBC-45d/s dating back to 2001, may not be attributable to UPD development. This wetland is the most disturbed of any of the UPD wetland locations: it is located within a power line corridor, a gravel road bisects the wetland, Novelty Hill Road crosses at the downstream end of the wetland less than 125 m from the amphibian sampling location, and illegal dumping of garbage, car parts, refrigerators, etc., is common. Concentrations for 30 metals were measured for samples collected in January, February, and April 2006. None of the BBC-45d/s samples exceeded state acute or chronic standards, so high concentrations of metals do not help explain these high mortalities. The pattern of egg dispersal also seems to be unusual in BBC-45d/s with egg masses frequently found in shallow (< 1ft) water, directly on the wetland substrate unattached to vegetation, and in clumps of three to over ten egg masses in one location. In contrast, in other wetlands, egg masses are typically attached to vegetation submerged beneath the water surface but above the wetland substrate with 2 to 3 egg masses adjacent to each other at most. Additional monitoring or water quality testing may be warranted in future years to help identify possible sources for the extremely high egg mass mortality and should include investigating whether the eggs are fertilized or sterile. Despite the high egg mass mortality in BBC-45d/s, Northwestern salamander egg mass abundance is not declining.

Threshold Exceedance Criteria and Evaluation

Amphibian threshold exceedance criteria are violated if:

1. Species richness: Any one species that formerly bred in the wetland disappears for two consecutive years.
   - Species richness of breeding amphibians has fluctuated across the monitoring period with no clear links to the timeline of UPD development (Figure 10).
   - 2007 species richness was the same as at least one year of predevelopment richness at all wetland locations. This includes BBC-44, where Pacific treefrogs were not observed in 2007 for the first time since 2002.

2. Abundance: Significant reduction in abundance of egg masses of Northwestern salamanders or Northern red-legged frogs[23] for two consecutive years.
   - Northwestern salamander egg mass abundance declined for 2 consecutive years from 2002 to 2004 at two wetland locations including BBC-45d/s (80 to 46 to 39) and BBC-45u/s (20 to 3 to 0) (Table 6). These declines took place after limited 2001 clearing but prior to extensive 2005 clearing and development, and abundances have since rebounded to peak (BBC-45d/s: 87 in 2006) or near-peak (BBC-45u/s: 13 in 2007) levels.
   - Northern red-legged frog egg mass abundance declined for 2 consecutive years from 2000 to 2002 at one wetland location – BBC-45u/s (10 to 3 to 2) (Table 6). The decline from 10 in 2000 to 3 in 2001 took place prior to subbasin clearing and

[23] Pacific treefrogs were erroneously called out in the Trilogy monitoring plan (King County 2001) instead of Northern red-legged frogs. Northern red-legged frogs and Northwestern salamanders represent two different life strategies of pond-breeding amphibians with eggs that are easy to identify and detect and the monitoring protocols were designed with these two species in mind, not Pacific treefrogs.

development, and abundances have stayed relatively constant since then, fluctuating between 1 and 3 egg masses per year.

3. Mortality: Egg mortality increases by 20% or more for Northwestern salamanders or Northern red-legged frogs.
   - BBC-45d/s had high Northwestern salamander egg mass mortality levels (>27% on average) in 2001, 2002, 2005, 2006, and 2007 (Figure 11). The 2001 mortality spike (35.7%) occurred before most UPD-related clearing and development within the subbasin and represents predevelopment conditions. Only 2007 mortality (67.3%) represents more than a 20% increase in egg mass mortality. However, only very limited UPD subbasin clearing had taken place prior to the 2002 mortality spike (54.3%); therefore, the egg mass mortality may be unrelated to UPD development. Even prior to UPD development, this wetland was the most disturbed onsite wetland (see discussion above). Nevertheless, mortality rates and associated water quality parameters should be monitored closely in future years to try to determine the source of these high mortalities.
   - Northern red-legged frog egg mass mortality never increased by more than 20% at any of the wetland locations.

Corrective Actions

The exceedances noted above should be monitored closely, but none can be directly linked to UPD development and no corrective actions are recommended.

3.4 Fish

Fish are commonly used bioindicators presumed to reflect cumulative impacts to an aquatic environment because they react to changing chemical and physical properties, including those associated with increased urbanization and impermeable surface area such as decreased water quality or increased channel erosion and deposition (Booth and Jackson 1997). Wang et al. (2001) suggest that urban development that minimizes connected impervious surfaces[24] and preserves undeveloped buffer areas should have less impact on stream habitat and fish than conventional types of development. The 200-ft. (60-m) average buffering employed on all streams and wetlands within the UPD boundaries models this buffer preservation approach. Fish sampling on four streams draining the UPDs (Adair, Colin South, Evans East, and Wallace Creeks) tests whether UPD development impacts fish populations (Figure 12).

Only Adair Creek was sampled in 2007. See Appendix G for more details on the fish sampling schedule through 2007.

[24] Wang et. al (2001) uses the definition for connected impervious surfaces described by Booth and Jackson (1997): those surfaces impervious to infiltration by precipitation (e.g., roads, sidewalks, parking lots, roofs) that have a direct hydraulic connection (e.g., surface drainage way, storm sewer) to the downstream drainage system.

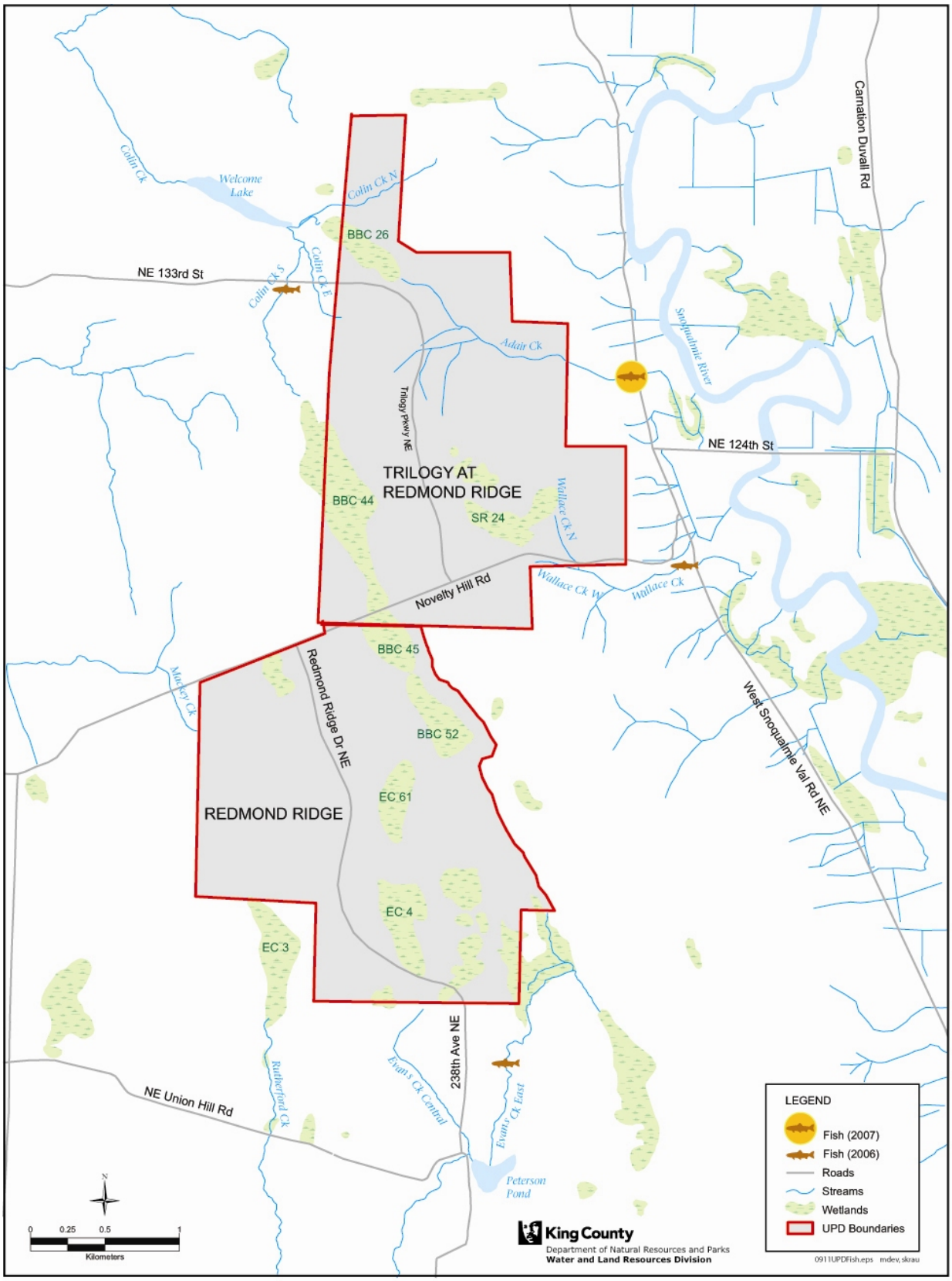

Figure 12. Fish sampling locations.
Fish sampling was conducted at Adair Creek in 2007.

Modifications

The Redmond Ridge monitoring plan (King County 1999) calls for fish monitoring beginning in the first year of construction and annually for 6 years[25]. As proposed in the Trilogy monitoring plan (King County 2001) fish sampling at all required streams will be conducted at years 1, 3, and 5 following 75% subbasin buildout (Appendix G).

Rutherford and Evans Central Creeks were named in the Redmond Ridge monitoring plan (King County 1999) for fish sampling. However, Rutherford Creek was never sampled because silt and mud substrate in the reach immediately downstream of the UPDs impairs the ability to see and catch fish and because fish habitat was already considered degraded prior to UPD construction (Comings et al. 2000). Evans Creek Central was excluded because of the presence of unsuitable fish habitat including silt-laden substrate and sluggish flow (Comings et al. 2001a).

Adair, Wallace, and Colin South Creeks were named in the Trilogy monitoring plan (King County 2001) for fish sampling. Wallace Creek has been removed from the monitoring schedule because of an inability to gain property-owner permission to conduct fish sampling. Relocating the sample reach would not allow a comparison of pre- and post-development conditions.

The Redmond Ridge and Trilogy monitoring plans (King County 1999, 2001) outline one-pass and four-pass electrofishing techniques, respectively. Since 2006, three-pass electrofishing depletion methods have been used (see 'Procedures' section below). One pass does not allow any estimation of population size, yet the likelihood of fish mortality as a result of electrical currents increases with each additional electrofishing pass. Three passes were deemed sufficient to see reduced fish abundance between passes.

Sampling recommendations – Continue three-pass electrofishing sampling at Adair, Colin South, and Evans East Creeks. Reduce frequency to a 1, 3, 5 year plan for all creeks. Reinitiate Wallace Creek sampling if property access permission is given, otherwise omit it. Exclusively use nets with smaller mesh size (e.g., < 6-mm [0.2-in]) to reduce the chance of captured fish escaping through the nets.

Procedures

Crews used four-pass electrofishing removal/depletion methods in 1991 and 2000 and three-pass methods in 2006 and 2007 to survey fish within reaches either approximately 60- or 100-m (196- to 328-ft) in length[26] (Zippin 1956, 1958, Platts et al. 1983). Since 2000, surveys have been conducted in June; however, 1991 sampling took place in August, September, or December[27]. At each site, crews used a Smith-Root type VII electrofisher with dip nets to collect fish that were transferred to aerated buckets when captured and held until each pass was completed. Between each pass, every fish was identified to species and its length measured[28] prior to being

[25] In contrast to the Redmond Ridge monitoring plan, Section X of the Redmond Ridge Master Drainage Plan (Hugh G. Goldsmith and Associates 1996) outlines fish use evaluation beginning 3 years after 75% buildout in each subbasin and continuing annually for 3 consecutive years.
[26] Sample reaches were ~ 60 m in length in 1991 and 92-100 m in length in 2000, 2006 and 2007.
[27] Evans East was sampled in December 1991 because the channel was dry in September 1991.
[28] In 2006, fish length was estimated into four size classes: 0-50, 50-100, 100-150, and >150-mm. Fork length was recorded in 2000 and total length was recorded in 2006 and 2007.

released downstream of the sample reach. In 1991, fish were sedated with MS-222 (tricaine methanesulfonate) to facilitate handling. Sedatives were not used in subsequent surveys.

Downstream block nets were always used to prevent migration in or out of the reach and nets were also placed at the upstream end in 2000 and 2007. In 2006, the upstream stopping point was selected at a habitat break (e.g., a riffle or gradient break) based on its perceived ability to maintain a closed population.

Population estimates and 95% confidence intervals were calculated from depletion sampling using the methods and formulas outlined in Lockwood and Schneider (2000). However, these estimates are inherently variable. Therefore, to make comparisons across years, the three-pass cumulative abundance for each species was calculated.

Results

In 2007, 174 fish were collected in Adair Creek including 74 coho (*Oncorhynchus kisutch*), 33 cutthroat trout (*Oncorhynchus clarki*), 55 rainbow trout (*Oncorhynchus mykiss*), and 12 riffle sculpin (*Cottus gulosus*) (Table 7). In addition to the fish, crews also captured 27 Pacific giant salamanders (*Dicamptodon tenebrosus*) and two crayfish (*Pacifasticus leniusculus*)[29].

Table 7. Summary by species and pass for 2007 Adair Creek fish sampling.

	Catch/pass				Population Estimate		Length characteristics (mm)			
Species	**1**	**2**	**3**	**Total #**	**Pop Est.**	**95% CI**	**Mean**	**SD**	**Median**	**Range**
Coho	44	18	12	74	82	72 - 92	60.4	9.8	63	34 - 80
Cutthroat	16	9	8	33	42	28 - 56	42.6	11.6	40	34 - 103
Rainbow	38	10	7	55	57	53 - 61	43.1	12.7	41	36 - 110
Sculpin	7	4	1	12	12	12 - 20	82.9	6.8	84	73 - 98

Species Richness

Adair Creek fish species richness has increased by one for every year of sampling (Table 8). Cutthroat trout have been present every year since 1991. Coho salmon were first found in 2000, riffle sculpin (*Cottus gulosus*) in 2006, and rainbow trout (*Oncorhynchus mykiss*) in 2007.

Table 8. Species collected during four electrofishing sampling dates on Adair Creek.
1991 data were collected in August. 2000, 2006, and 2007 sampling was conducted in June.

Year	Species observed
1991	cutthroat
2000	cutthroat, coho
2006	cutthroat, coho, riffle sculpin
2007	cutthroat, coho, riffle sculpin, rainbow trout

Although it is promising to have not observed the disappearance of cutthroat trout in any of the streams since the onset of development, it is important to note that high quality coldwater streams naturally have relatively few species. Whereas environmental degradation is frequently associated with decreases in species richness in warmwater streams, it is typically linked to an increase in species richness in coldwater streams as a result of the inclusion of non-native

[29] The electrofishing surveys were not designed to estimate amphibian or crayfish populations; therefore, only presence or absence was noted, and abundance estimates were not made for these species.

warmwater species (Lyons et al. 1996). However, in the case of Adair Creek, the collected species were all native and commonly dominant in coldwater systems.

Downstream fish passage improvements and/or releases of juvenile salmon through the Washington Department of Fish and Wildlife (WDFW) Salmon in the Classroom program[30] could explain the presence of coho since 2000 after they were not found in the initial 1991 survey.

Sculpins were only observed in 2006 and 2007; however, they are frequently missed when electrofishing because they are benthic species. Benthic fish swim in short bursts and sink when stunned, making them more difficult to capture with electrofishing methods because their coloration camouflages them against the stream substrate and increased water column turbidity during sampling decreases visibility (Cowx and Lamarque 1990, B.C. Ministry of Environment 1997). Additionally, results could vary, primarily in the deeper pool habitats, if field personnel in the 1991 and 2000 sampling seasons concentrated fishing efforts at the top or middle of the water column relative to where the 2006 and 2007 field crews concentrated their efforts (potentially more thoroughly throughout the water column or biased towards the bottom of the water column). Therefore, it is possible that sculpin have always been present in the sample reach of Adair Creek.

Rainbow trout were observed for the first time in 2007. Features and colors vary greatly among fish. Distinguishing rainbow trout from cutthroat trout when the fish are smaller than 80-mm (3.1-in) is very difficult even for experienced biologists (Pollard et al. 1997). Of the 55 rainbow trout observed in 2007, only 2 were greater than 50-mm (2-in) in length. However, the presence of the two larger fish (103- and 110-mm [4.1- and 4.3-in]) allowed the WLRD fish sampling crew to positively confirm the rainbow trout identification.

Abundance

Table 9 shows totals of three-pass electrofishing surveys in 2000, 2006, and 2007 for Adair Creek. For population estimates see Appendix H. The number of coho found in each sample has increased from a 2000 preconstruction count of 30 to a post-construction count of 74. In contrast, cutthroat numbers dropped from 119 in 2000 to 10 in 2006 and 33 in 2007. Because of the difficulties in distinguishing some juvenile salmonids from one another (see description above), Table 9 includes a row that combines coho, cutthroat trout, and rainbow trout into overall 'salmonid' abundance. According to this measure, salmonid numbers in 2000 (149) and 2007 (162) are similar with a low in 2006 (69).

[30] In 1994, the Laura Ingalls Wilder Elementary School began to participate in the Salmon in the Classroom program. They release juvenile salmon to at least Colin Creek South (http://schools.lwsd.org/wilder/watershed.htm). Fish survival from these releases is presumed to be quite low and it is not known whether fish were released to Adair Creek.

Table 9. Three-pass electrofishing totals for fish species at Adair Creek (2000, 2006- 2007).
Salmonids is the sum total of coho, cutthroat trout, and rainbow trout. Data are from June each year.

Species	2000 Preconstruction	2006 During Construction	2007 Post-construction (after 75% buildout)
Coho	30	59	74
Cutthroat trout	119	10	33
Rainbow trout	0	0	55
Sculpin	0	15	12
Salmonids	149	69	162

See Appendix I for the raw 2007 fish data.

Threshold Exceedance Criteria and Evaluation

Fish threshold exceedance criteria are violated and could trigger appropriate corrective actions if fish communities (King County 2001) or fish abundance estimates (King County 1999) decline by greater than 20% compared to baseline and other monitoring data through time.

Cutthroat trout abundance declined from 2000 baseline levels of 119 to 33 fish in 2007 (Table 9), a decline of 72.3%. Fish populations fluctuate naturally, and in addition to personnel changes between years reducing sampling and species identification consistency, there are a number of confounding factors (e.g., climate, ocean conditions, predation, displacement by coho salmon, development elsewhere and within the subbasin, downstream conditions affecting migration) affecting fish abundance. Difficult field sampling conditions (i.e., dense riparian vegetation that is difficult to maneuver through, shallow water that makes netting fish difficult and the abundance of small fish, which are hard to see and sometimes slip through the nets) only increase the year-to-year fluctuations. Therefore, without comprehensive baseline data establishing the range of natural predevelopment variability or sampling efficiency variation, it is difficult to determine whether the observed decline in cutthroat trout abundance in 2006 and 2007 was a result of natural fluctuations, increased urban development, or even differences in sampling efforts.

Because of the difficulty and unreliability in assessing abundance in addition to the relative species paucity at Adair Creek (Table 8) and all UPD streams during 1991 and 2000 baseline sampling, the threshold exceedance criteria will be changed to the following: no species present before UPD development should disappear in any sampling season.

Corrective Actions

Based on the reasons discussed above, no corrective actions are recommended.

3.5 Wetland Vegetation

Wetland vegetation monitoring is limited to assessments of Wetland BBC-52 in even years starting in 2000 and continuing for 4 years (two sampling seasons) after 75% buildout (King County 1999). No vegetation monitoring occurred during 2007; the next monitoring will take place in July 2008.

Modifications

In addition to BBC-52, BBC-45 was listed as a sampling location in the Redmond Ridge monitoring plan (King County 1999) "if time allows." However, no sampling has ever been conducted at BBC-45.

Sampling recommendations – Continue vegetation sampling in even years. Sampling crew continuity should be maintained as much as possible to reduce between-sampler variations.

3.6 Wetland Hydrology

The Trilogy monitoring plan (King County 2001) calls for continuous water level monitoring at wetlands BBC-44 and SR-24B and crest-stage gages at SR-24A, SR-24C, SR-24D, BBC-26, and BBC-45. The Redmond Ridge monitoring plan (King County 1999) includes continuous water level monitoring at wetlands BBC-UN1, BBC-45, BBC-52, EC-61, EC-4 and EC-3 (Figure 13). See Appendix J for the wetland hydrology sampling schedule through 2007.

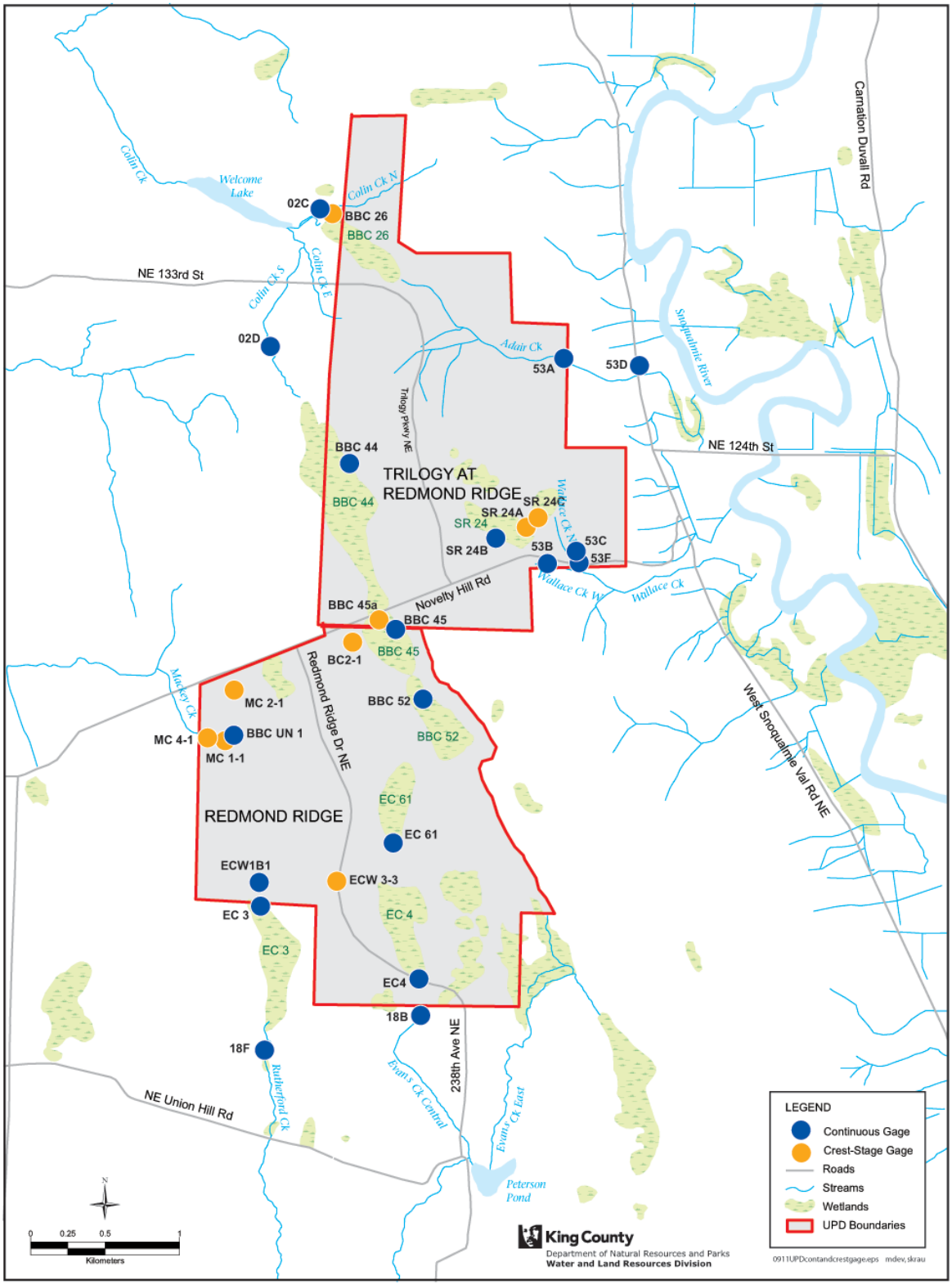

Figure 13. Location of wetland, stream, and facility hydrology monitoring.
17 continuous gages (2 bypass, 7 streams, and 8 wetlands) and 8 crest-stage gages (5 facilities and 3 wetlands) were monitored in 2007.

Monitoring of wetland hydrology commenced after September 2000 as tabulated in Table 10. This timeframe was prior to 75% buildout in most subbasins.

Table 10. Gage type and monitoring dates for wetland hydrology monitoring.

Site	Predevelopment			Post-development		Basin	Construction Start	75% Buildout
	Type	Begin	End	Type	Begin			
Trilogy								
BBC-26	Crest-stage	5/8/90	6/21/94	Staff	9/8/00	NWD	2003	Oct-06
BBC-44	Crest-stage	6/26/90	4/22/94	Recording	1/19/01	SWD	2001	Aug-02
BBC-45a	Crest-stage	6/26/90	6/9/94	Crest-stage	1/2/01	SWD	2001	Aug-02
SR-24A	Crest-stage	9/19/90	5/31/94	Crest-stage	4/17/02	SED	2001	Sep-05
SR-24B	Crest-stage	9/30/90	5/31/94	Recording	10/17/00	SED	2001	Sep-05
SR-24C	Crest-stage	9/30/90	5/31/94	Crest-stage	5/21/02	SED	2001	Sep-05
SR-24D	Crest-stage	10/31/90	5/31/94	Crest-stage	N/A	SED	2001	Sep-05
Welcome Lake	Crest-stage	N/A	N/A	Crest-stage	11/28/00		2001	Jun-06
Redmond Ridge								
BBC-45	Staff	6/30/87	6/30/91	Recording	10/17/00	BBC	2001	N/A
BBC-52	Staff	6/30/87	6/30/91	Recording	10/19/00	BBC	2001	N/A
BBC-UN1	Staff	6/30/87	6/30/91	Recording	3/30/05	MC	1998	Sep-01
EC-3	Staff	6/30/87	6/30/91	Recording	5/17/02	ECW	1999	Oct-03
EC-4	Staff	6/30/87	6/30/91	Recording	3/28/02	ECC	2000	Oct-05
EC-61	Staff	6/30/87	6/30/91	Recording	3/28/02	ECC	2000	Oct-05

Modifications

Site visits were made less frequently than monthly, particularly after 2006 when King County gaging staff numbers were reduced. The recorder at EC-4 failed in 2004 and was replaced with a crest-stage gage. BBC-UN1 was operated as a flow gage in the flow control structure that discharges to facility MC-4.

Sampling recommendations – No field sampling changes are recommended. Run the Trilogy Hydrological Simulation Program-Fortran (HSPF) model with current rainfall conditions for the 2008-2010 monitoring report. The Redmond Ridge HSPF model will require hand entry of the input files, which will be done if feasible.

Procedures

Wetland hydrology procedures are divided into an overview of methods followed by brief descriptions of the different instrumentation used for monitoring and a summary of analysis methods.

Overview

Predevelopment (also called 'baseline') observations are available from 1990-1994 for Trilogy wetlands and from 1987-1991 for Redmond Ridge wetlands. Monitoring for the current 'post-development' monitoring period began between 2000 and 2005 depending on the site (see Table 10). A survey of the wetland staff gages in the Trilogy development was initiated in 1990 (Northwest Engineering Company 1990). The results were tabulated and made available to the King County project team, who converted the observed stage readings and recorded water levels to elevations based on the survey results. The staff gages used for baseline Redmond Ridge

wetland monitoring were used for BBC-UN1, EC-3, and EC-61, and they are presented as water surface elevation. The baseline staff gages were not found for BBC-45, BBC-52, and EC-4. The wetland levels for those sites are based on readings of the staff gage installed at the site or on estimated gage datum.

In general, wetland sites were visited on average ten times a year, although fewer visits were made starting in 2005 because of reductions in gaging staff. Various electronic data loggers and water level instruments were employed for measuring and recording wetland levels. The data loggers produced a time series of water levels generally at 15-minute intervals. The recorded water levels were adjusted to the observed wetland gage readings and stored in the WLRD hydrologic database (available online[31]). Field notes, data analyses, and quality control documents are kept in hard copy files for each site.

Instrumentation Descriptions

Wetland hydrology monitoring has utilized staff gages, crest-stage gages, and continuous recording gages. Below each type of equipment is briefly described.

Wetland water level monitoring is performed by first establishing a reference point called a gage datum to compare the water level to. The water level relative to the gage datum is called the gage height or stage. Frequently a post is driven into the wetland bed and a point on the post is established as the reference point. This is the staff gage. Alternatively, an existing structure over the water such as a bridge deck may be used as the reference point. The gage height is determined by measuring up or down to the water surface. Some sites have a graduated scale installed to directly read the gage height. Gage datum is a local datum that is independent of any survey datum. The elevation of the gage datum may be determined by survey and the readings converted to elevations above a national geodetic datum by adding the elevation of the gage datum to gage readings.

A crest-stage gage is a staff gage with an added device that indicates the highest stage attained during a period. A typical crest-stage gage consists of a two-inch diameter PVC pipe, capped on the bottom with holes to let water in. The pipe is attached to the staff gage or another post in the water. A smaller pipe or rod is placed in the two inch pipe with dried cork granules. The dried cork floats up with the water level and adheres to the indicator rod when the water level recedes leaving behind a precise and easily readable line. The cork line is compared to the gage datum to indicate the crest-stage reading. The rod is wiped clean and the cork recharged each site visit.

Continuous water level monitoring is accomplished by adding gage instruments that sense and record water level. Water level sensors used for this project[32] include digital shaft encoders which consist of a float and pulley system that converts the rotational position of the pulley to vertical distance, capacitance probes which use the conductive property of water to create

[31] http://green.kingcounty.gov/wlr/waterres/hydrology/

[32] The water level recorders initially purchased (AquaRod water level recorders) were not reliable and failed after five years of use. In 2005 WLRD started replacing them with a more reliable and accurate device. By January 2006, six of the eight continuously monitored wetlands had new water level recorders. At EC-3 WLRD continued to use equipment from a discontinued project. The water level recorder at EC-4 was not replaced after it failed in April 2006.

varying capacitance in a tube as the water level changes, and pressure sensors which return a varying voltage signal as water pressure deflects a diaphragm integrated into electronic circuitry. The sensors are operated by programmable data loggers. Data loggers turn on the sensors at scheduled intervals, process the signal, and store the readings. The data logger settings are programmed and recorded data are retrieved with a portable computer. The AquaRod capacitance probes and Onset U20 pressure loggers used on the project integrate the sensor and data logger into one sealed package. Unidata data loggers can interface with a number of different sensors that plug into the data logger and can be replaced if necessary.

Analysis Methods

The goal of the hydrologic monitoring program is to determine if wetland water levels exceed threshold criteria, described as deviations of greater than 20% from preconstruction parameters or that the range of wet weather water levels changes significantly (King County 1999, 2001). For streams and wetlands receiving stormwater, post-development target levels were modeled using HSPF[33]. These wetland performance goals are described in an HSPF Modeling Report[34] (Otak Incorporated 2007) and are summarized here:

1. Post-development[35] maximum annual water levels will increase by no more than 1.0 foot over pre-developed levels for 1.01- to 100-year return periods.
2. Post-development winter (November-March) median water levels will change by no more than 0.5 feet over pre-developed levels.
3. Post-development mean June 30 water levels will change by no more than 0.25 feet over pre-developed levels and standard deviation of June 10 water levels will change by no more than 0.25 feet.
4. Post-development spring/summer (April-October) median water levels will change by no more than 0.25 feet over predevelopment levels.
5. Post-development spring/summer (April-October) water level duration curves match predevelopment curves to within a maximum of 0.5 feet at all durations.

The modeling of post-development conditions with stormwater controls necessarily assumed that the existing beaver dams and berms that control the wetland levels were unchanged except where engineered control structures were planned (e.g., EC-4 and EC-61). Modeling relied on pre-development hydrologic data to predict post-development target levels for each of the five elements. Water level duration curves are presented only in the stream hydrology section later in the report. These modeled target levels are compared to post-development data (referred to as 'monitoring results' in the summary tables) and differences that exceed the thresholds are reported. There are no modeled target levels for SR-24C, SR-24D, or BBC-UN1 and therefore these comparisons are omitted for those locations.

[33] HSPF is a comprehensive package for simulation of watershed hydrology and water quality (Bicknell et al. 1997).
[34] The HSPF model report for Trilogy included all five elements in evaluating post-development performance. The model inputs and results are available electronically. The Redmond Ridge hydrologic and hydraulic analysis is available only in hard copy in the Northridge Master Drainage Plan (Hugh G. Goldsmith and Associates 1996). It provides wetland level flood frequency analysis, and charts of seasonal wetland level duration exceedance curves. Printouts of model control (uci) files are included in the calibration report.
[35] For the hydrology sections of this 2007 report, 'post-development' refers to the current monitoring period starting as early as 2000 for some wetlands (see Table 10). In future reports, post-development may be defined differently.

For each continuous recording station, charts present the daily maximum water level overlain with the maximum 24-hour rainfall intensity for each day. As appropriate, post-development target water levels for 1-, 2-, or 100- year return periods are inserted in the charts for reference. Where data gaps exist because of battery or equipment failure, mean daily wetland water levels are estimated from visual observations or behavior of nearby wetlands. All pre-development wetland hydrology data are based on periodic observations of staff or crest-stage gages. Where available, these data are charted; however, they are not displayed on the same chart as the continuous data.

For each staff or crest-stage station, charts present the wetland water level observations for both monitoring periods for comparison. Median winter and summer values are calculated; however, these values are crude because of the irregularity of the readings. The observation closest to June 30 each year is used to calculate a June 30 mean.

Results

Wetland water level data from the continuous recorders and crest-stage gages are presented by UPD and station in the sections below. Comparison to the threshold criteria is made in the discussion of results for each monitoring location and summarized at the end.

Trilogy

BBC-44

Continuous recording of BBC-44 water level began January 2001. The original water level recorder failed and was replaced in June 2006. Estimates of mean daily water level were made for 251 days between 2001 and 2006 from observations[36] and the water level record of nearby wetlands. Wetland levels were referenced to observations of a staff gage installed in the wetland in 1990 for baseline monitoring. The annual maximum wetland levels did not exceed the threshold criteria of less than one-foot rise over predevelopment levels for return periods 1.01 – 100 year (Figure 14).

[36] BBC-44 has a crest-stage gage that was read each site visit.

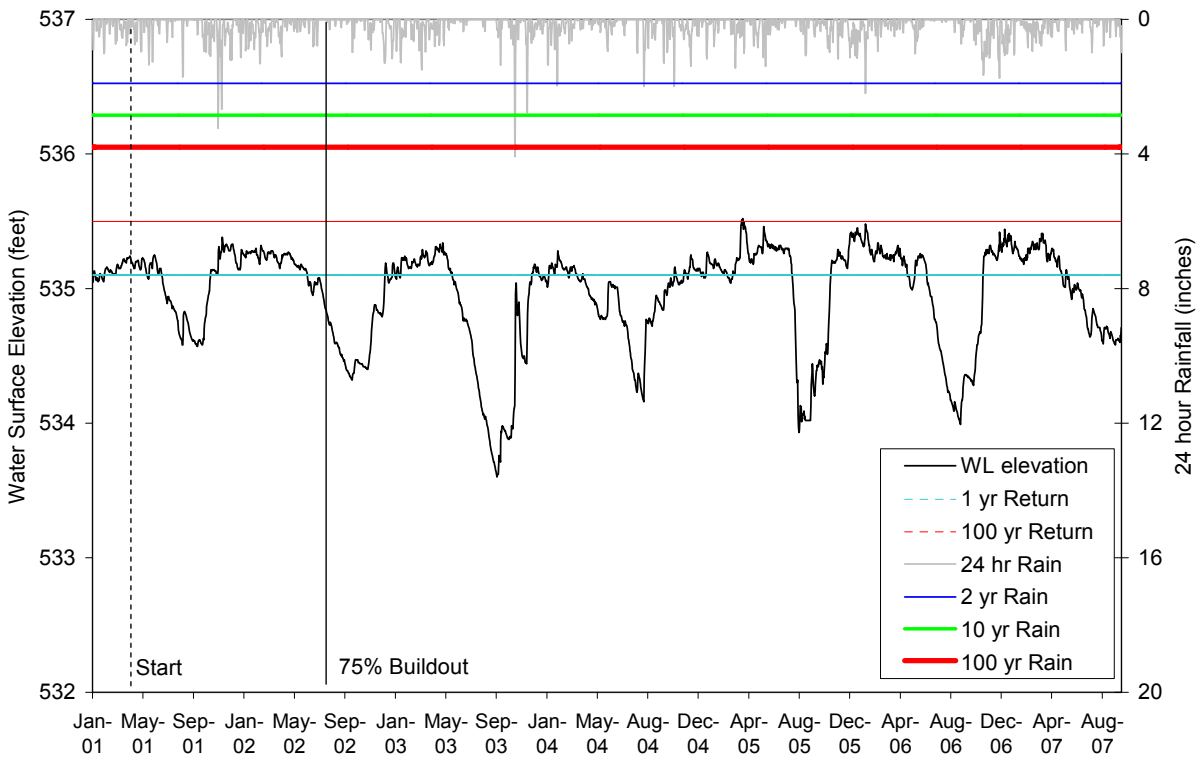

Figure 14. BBC-44 water surface elevations and daily rainfall totals (2001-2007).
January 19, 2001 to September 30, 2007. UPD construction began in 2001 (start) and 75% buildout was reached in August 2002.

Winter and summer median and June 30 mean threshold exceedance criteria have not been exceeded (Table 11). The monitoring data and observations indicate that the stormwater controls have been effective in meeting wetland performance objectives at BBC-44.

Table 11. Winter and summer median and June 30 mean water levels (ft) at wetland BBC-44.

	Winter Median	Summer Median	June 30 Mean
Target level	535.04	534.87	534.95
Monitoring result	535.18	534.99	534.99
Difference	0.14	0.13	0.04
Threshold	0.5	0.25	0.25

SR-24B

Continuous recording of SR-24B water level began October 2000. The AquaRod water level recorder installed in 2000 was replaced in September 2005. A crest-stage gage installed in 2004 was used to confirm high water readings from the recorder. Estimates of mean daily water level were made for 100 days between 2002 and 2005 from observations and the water level record of nearby wetlands. Wetland levels were referenced to a staff gage that WLRD installed in October 2000[37]. The old gage was last observed in May 1994 and was not found in October 2000. The

[37] An Otak Incorporated memo (2004) conveys the results of a survey of the staff gage. The survey put the 0.00 point of the gage at 501.20 feet. That offset was applied to all the recorded water levels for SR-24B. Baseline wetland level data collected 1990 through 1994 was based on a different staff gage that was surveyed at that time, with the 0.00 point determined to be 498.69 feet.

annual maximum wetland levels did not exceed the threshold criteria of less than one-foot rise over predevelopment levels for return periods 1.01 - 100 year (Figure 15). Annual wetland fluctuations from 2000-2007 varied from 2.5 to 3.5 feet and were similar to the annual fluctuations observed during the predevelopment monitoring.

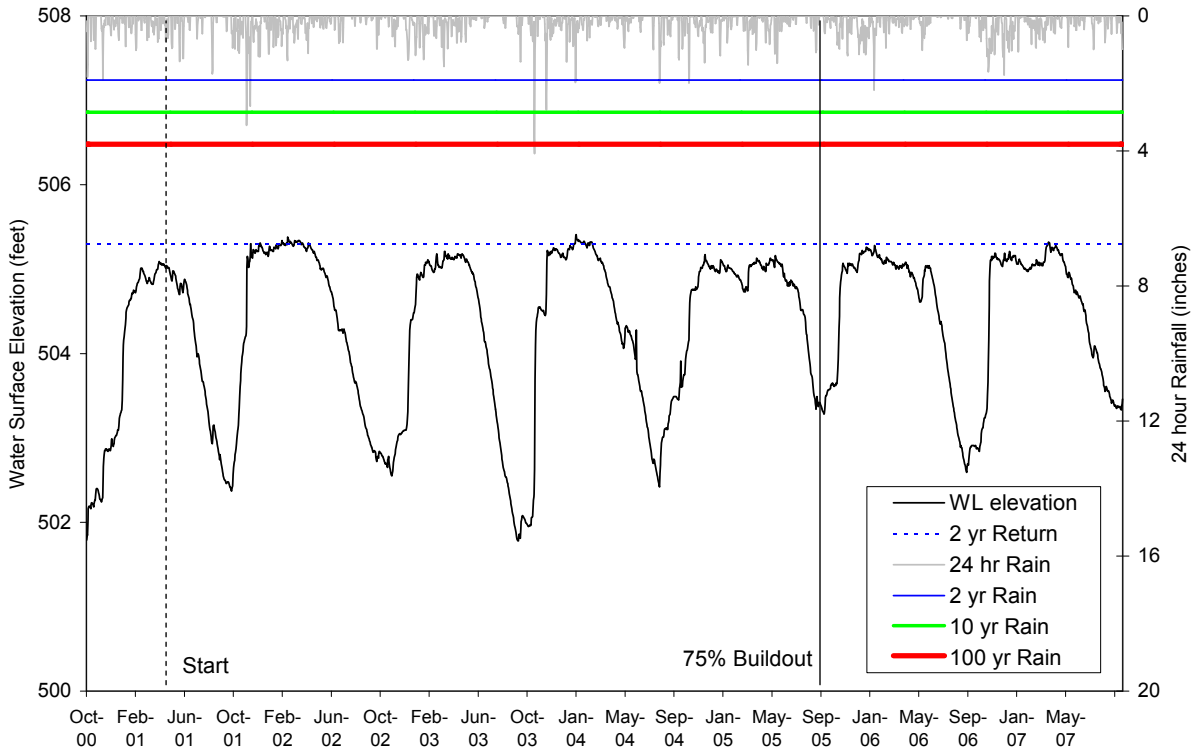

Figure 15. SR-24B water surface elevations and daily rainfall totals (2000-2007).
October 17, 2000 through September 30, 2007. UPD construction began in 2001 and 75% buildout was reached in September 2005.

The winter median, summer median, and June 30 mean levels all exceeded the threshold criteria compared to the modeled targets, suggesting the wetland level durations have been altered to hold water at a higher level (Table 12). These elevated winter and summer levels warrant further investigation to determine the hydraulic control for SR-24B.

It is possible that beaver or human activity has affected the outlet to the wetland in such a way to elevate the summer water level.

Table 12. Winter and summer median and June 30 mean water levels (ft) at wetland SR-24B.

	Winter Median	Summer Median	June 30 Mean
Target level	504.48	503.1	503.13
Monitoring result	505.04	504.37	504.34
Difference	0.56	1.27	1.21
Threshold	0.5	0.25	0.25

SR-24A

SR-24A is south of and separated from SR-24B by an old railroad berm, now a walking trail. Wetland levels are determined from observations of a crest-stage gage installed for baseline monitoring. There is no record of the gage datum being surveyed.

The peak annual predevelopment level was 5.57 feet (April 1991) after the large 1991 wet season compared to the peak post-development reading of 5.98 feet (February 2006) after a December - January wet spell. The data do not indicate an unacceptable rise in annual peak levels; however, smaller fluctuations in annual wetland levels in the post-development period after 2002 were observed (Figure 16).

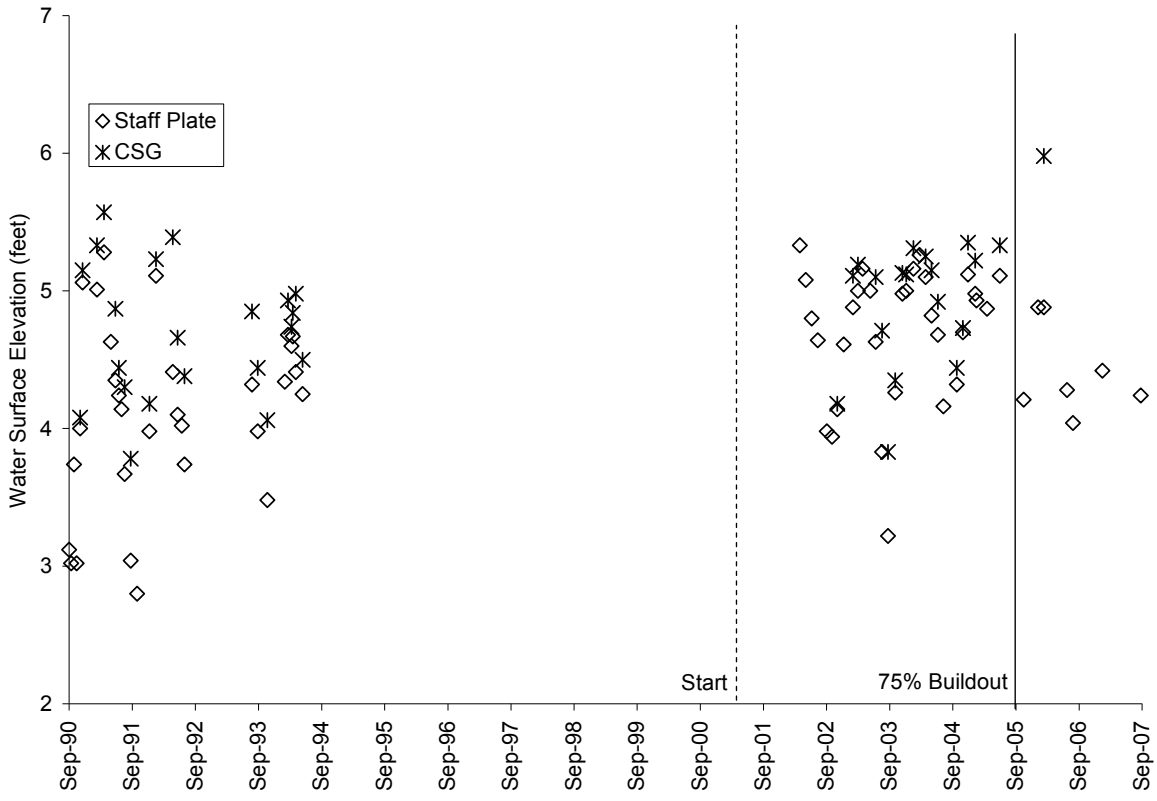

Figure 16. SR-24A water surface elevations (1990-1994, 2002-2007).
Both predevelopment (through 1994) and post-construction (construction began in 2001, 75% buildout was reached in September 2005) periods are shown. Staff plate readings are the direct observations of gage height made during site visits. Crest-stage readings (CSG) indicate the highest water level between site visits.

There are not enough observations to perform a valid statistical analysis of the readings, but median winter and summer levels and June 30 mean exceed the threshold criteria (Table 13). These observed changes may warrant further investigation to determine the hydraulic control, similar to SR-24B. Beaver activity near the outlet has been observed at SR-24A.

Table 13. Winter and summer median and June 30 mean water levels (ft) at wetland SR-24A.

	Winter Median	Summer Median	June 30 Mean
Target level	4.34	4.14	4.21
Monitoring result	4.88	4.76	4.61
Difference	0.54	0.62	0.40
Threshold	0.5	0.25	0.25

SR-24C and SR-24D

Wetlands SR-24C and SR-24D do not receive flow from stormwater facilities and therefore do not have modeled predictions. The SR-24D location was shallow in the predevelopment monitoring period and dry and difficult to find in the post-development period[38]. SR-24C wetland levels are determined from observations of a staff plate in the wetland installed for baseline monitoring with a gage datum of 495.53 feet (Northwest Engineering Company 1990). The annual peaks are higher and the annual fluctuations greater in the post-development period compared to predevelopment wetland level observations (Figure 17).

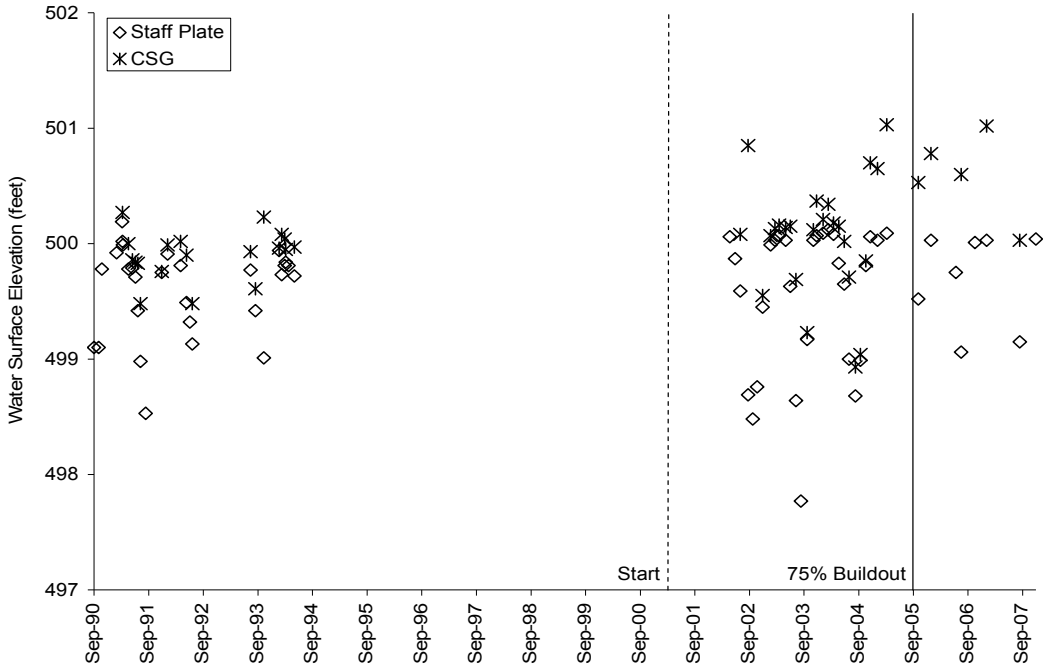

Figure 17. SR-24C water surface elevations (1990-1994, 2002-2007).
Both predevelopment (through 1994) and post-construction (construction began in 2001, 75% buildout was reached in September 2005) periods are shown. Staff plate readings are the direct observations of gage height made during site visits. Crest-stage readings (CSG) indicate the highest water level between site visits.

[38] The last time gage SR-24D was found was April 7, 2000 and no monitoring has been done since then.

BBC-45A

BBC-45A is located south of Novelty Hill Road and is separated from the main body of wetland BBC-45 by a maintenance road within a power line right-of-way. The wetland is connected to BBC-44 to the north by a culvert under Novelty Hill Road. Wetland levels are determined from observations of the original crest-stage gage installed in the wetland for predevelopment monitoring with a gage datum of 538.41 feet (Northwest Engineering Company 1990).

BBC-45A was included in the HSPF modeling for Trilogy. The modeled 1-year return level is 543.1 feet and 100-year return level 543.6 feet. The annual peak levels appear to be higher in the post-development period, but below the 1.0-foot threshold criteria rise for annual peaks (Figure 18).

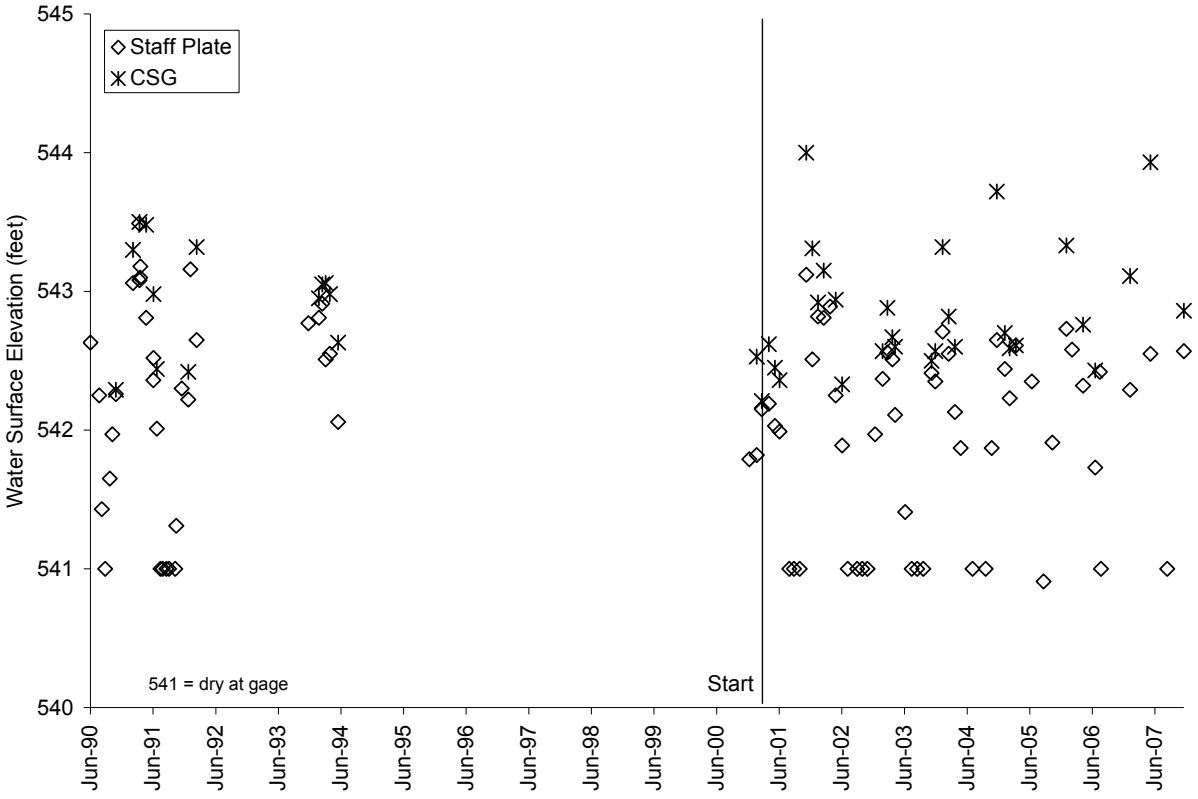

Figure 18. BBC-45A water surface elevations (1990-1994, 2001-2007).
Both predevelopment (through 1994) and post-construction (construction began in 2001, 75% buildout has not been reached in this subbasin) periods are shown. Staff plate readings are the direct observations of gage height made during site visits. Crest-stage readings (CSG) indicate the highest water level between site visits. A reading of 541 feet is shown for the time no water was observed at the staff gage.

Winter median water levels and June 30 mean levels exceed threshold criteria (Table 14.).

Table 14. Winter and summer median and June 30 mean water levels (ft) at wetland BBC-45A.

	Winter Median	Summer Median	June 30 Mean
Target level	543.00	542.13	541.46
Monitoring result	542.39	541.99	541.97
Difference	-0.61	-0.14	0.51
Threshold	0.5	0.25	0.25

BBC-26

BBC-26 wetland levels are determined from observations of a staff plate that was installed in the wetland for baseline monitoring with a gage datum of 408.02 feet (Northwest Engineering Company 1990). None of the observations during the reporting period exceeded the 5-year return target level (414.3 feet) by more than 0.7 feet, which is less than the threshold criteria of less than 1 foot rise in annual peaks (Figure 19). However, there appears to be a trend of increasing water levels starting in 2004 that should be monitored closely.

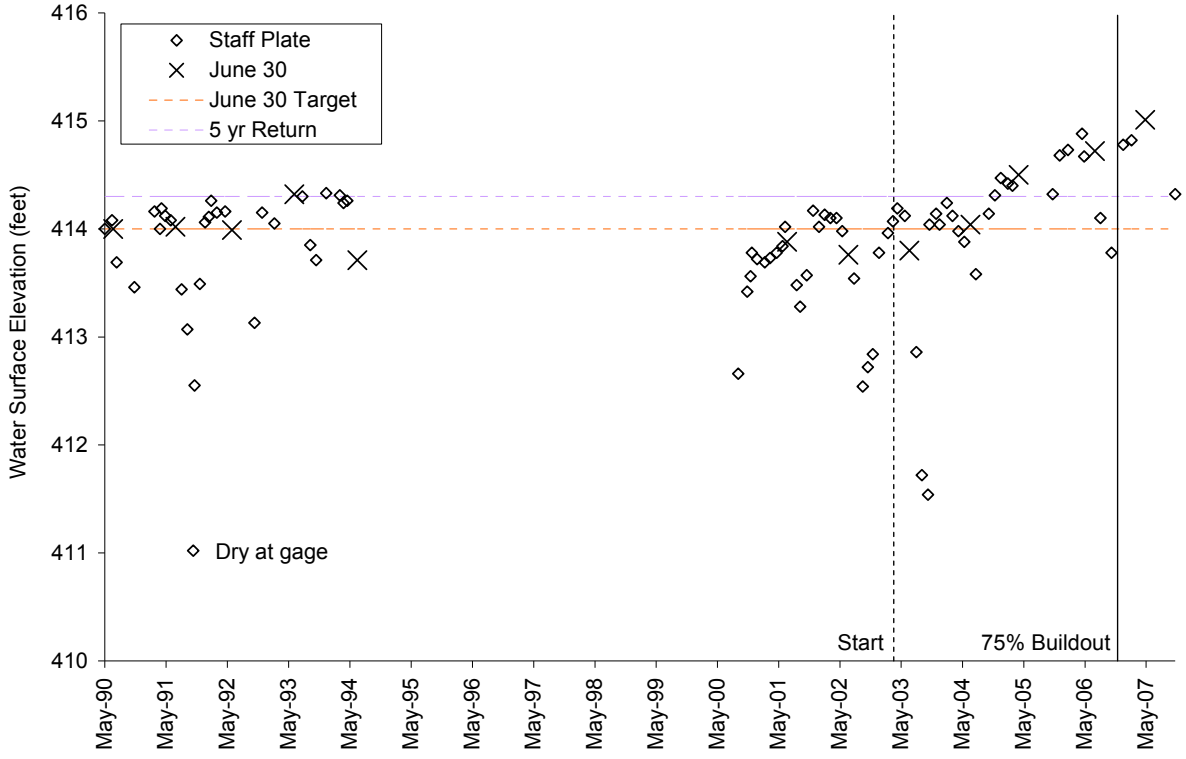

Figure 19. BBC-26 water surface elevations and June 30 water level (1990-1994, 2000-2007).
Both predevelopment (through March 2003) and post-construction (construction began in 2003, 75% buildout was reached in October 2006) periods are shown.

Redmond Ridge

BBC-45

BBC-45 is a scrub-shrub wetland hydraulically controlled by the power line access road south of Novelty Hill Road. The power line road has been re-graded since the baseline monitoring period. The road work may have changed the road bed elevation that constitutes the hydraulic control of the wetland. The effect on the culverts through the road bed is also not known.

Continuous level monitoring began October 2000. A staff plate, crest-stage gage, and AquaRod level recorder were installed immediately south of the power line road[39]. The AquaRod level recorder started failing in 2005 and was replaced. Because of the unreliable data generated from the failing level recorder, water levels for July 15 through September 15, 2005 are estimates based on the crest-stage reading and the nearby BBC-52 gage record.

The wetland level flowed over the power line road every wet season during the monitoring period (October 2000 through September 2007). The annual fluctuations from the baseline monitoring ranged from 1.2 to 2.8 feet (Figure 20). The post-construction annual fluctuations all are less than 2 feet (Figure 21). The peak wetland levels in 2005 through 2007 are elevated about 0.3 feet over the previous years, but never exceed the two year recurrence target of 541.1 feet. The annual peak water levels do not show exceedances of the wetland performance goals.

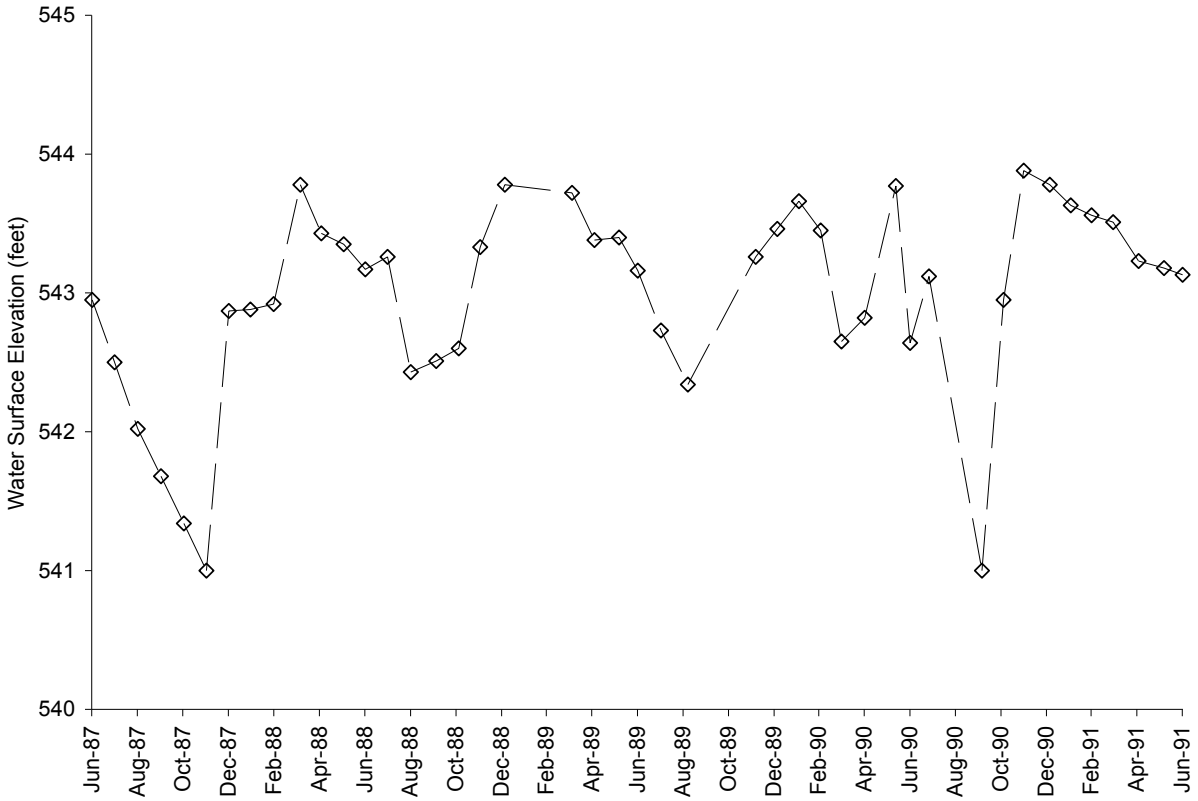

Figure 20. Water surface elevations at wetland BBC-45 (1987-1991).
All data are pre-UPD development.

[39] The staff plate was not surveyed and the gage used for baseline monitoring was not found. The new gage datum was estimated from a typical June 30 baseline reading and an offset was calculated to the staff gage.

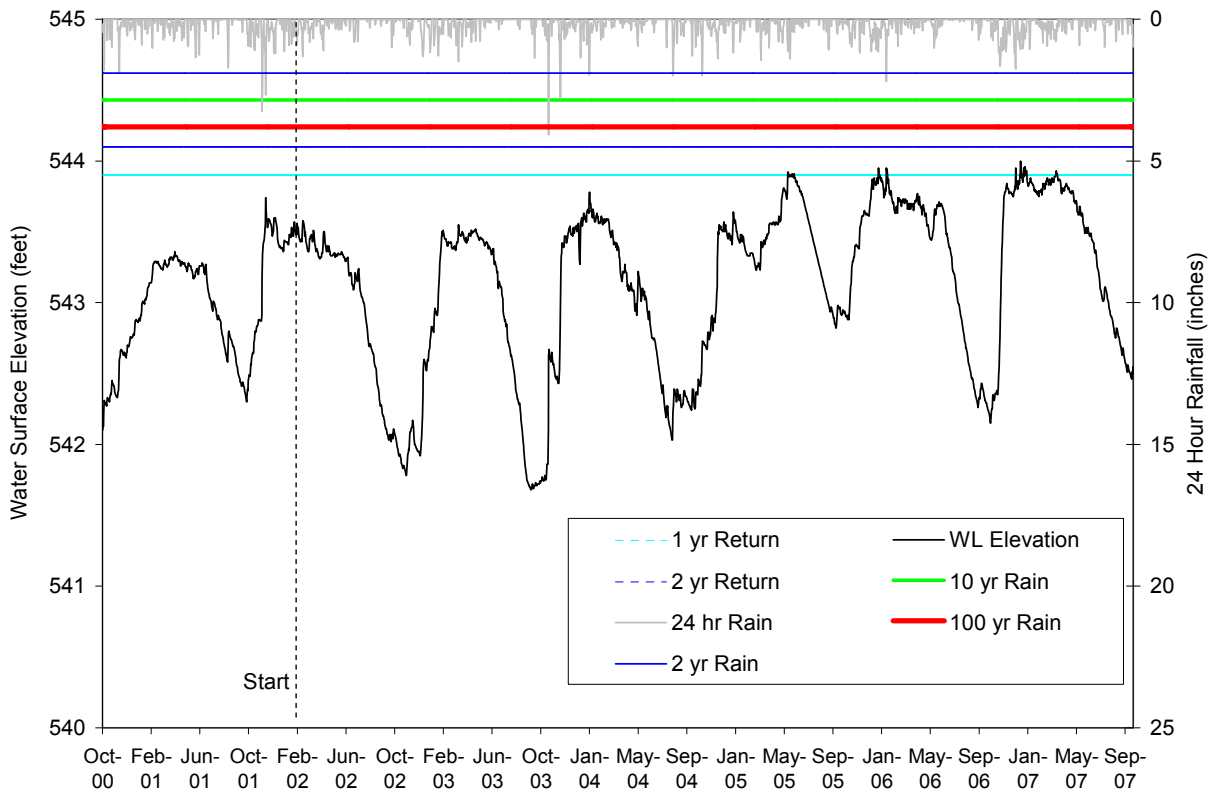

Figure 21. Water surface elevations at wetland BBC-45 and daily rainfall totals (2000-2007).
UPD construction began in 2001, 75% buildout has not been reached in this subbasin.

The mean June 30 reading increased to 543.7 for the seven observations in the monitoring period, an increase from the target of 543.1 feet exceeding the performance goal (Table 15). The change in summer and winter median levels are within the design goals. The gage datum should be surveyed for more accurate comparison to the baseline monitoring data peak level targets.

Table 15. Winter and summer median and June 30 mean water levels (ft) at wetland BBC-45.

	Winter Median	Summer Median	June 30 Mean
Target level	543.6	543.14	543.1
Monitoring result	543.36	543.26	543.7
Difference	-0.24	0.12	0.58
Threshold	0.5	0.25	0.25

BBC-52

BBC-52 is a scrub-shrub open water wetland hydraulically controlled by beaver dams and, to some extent, the water level of BBC-45. Continuous monitoring began in October 2000. A staff gage and level recorder were installed near the walking path and the wetland outlet[40]. The AquaRod level recorder was replaced in 2006.

[40] The staff plate has not been surveyed and the gage used for baseline monitoring was not found.

The wetland was dry at the surface near the gage in the summers of 2002, 2003, 2006, and 2007. The modeled maximum annual water level varied only 0.2 feet from the 1-year (547.74) to the 100-year (547.96) return intervals. The recorded levels during the monitoring period exceeded the modeled target levels, but by less than 1 foot (Figure 22). The annual fluctuations were 2-3 feet, similar to the baseline observations (Figure 23).

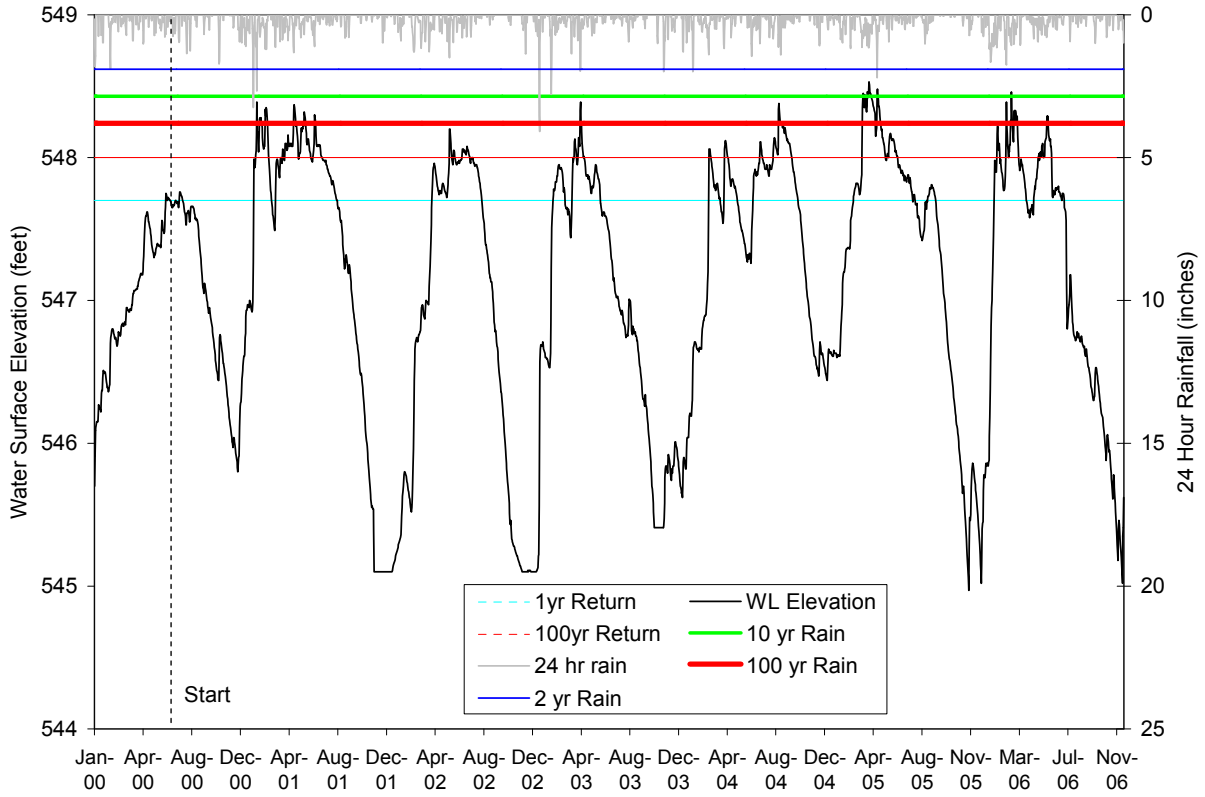

Figure 22. Water surface elevations at wetland BBC-52 and daily rainfall totals (2000-2007).
UPD construction commenced in 2001 and no date is projected for 75% subbasin buildout. The elevation datum is estimated.

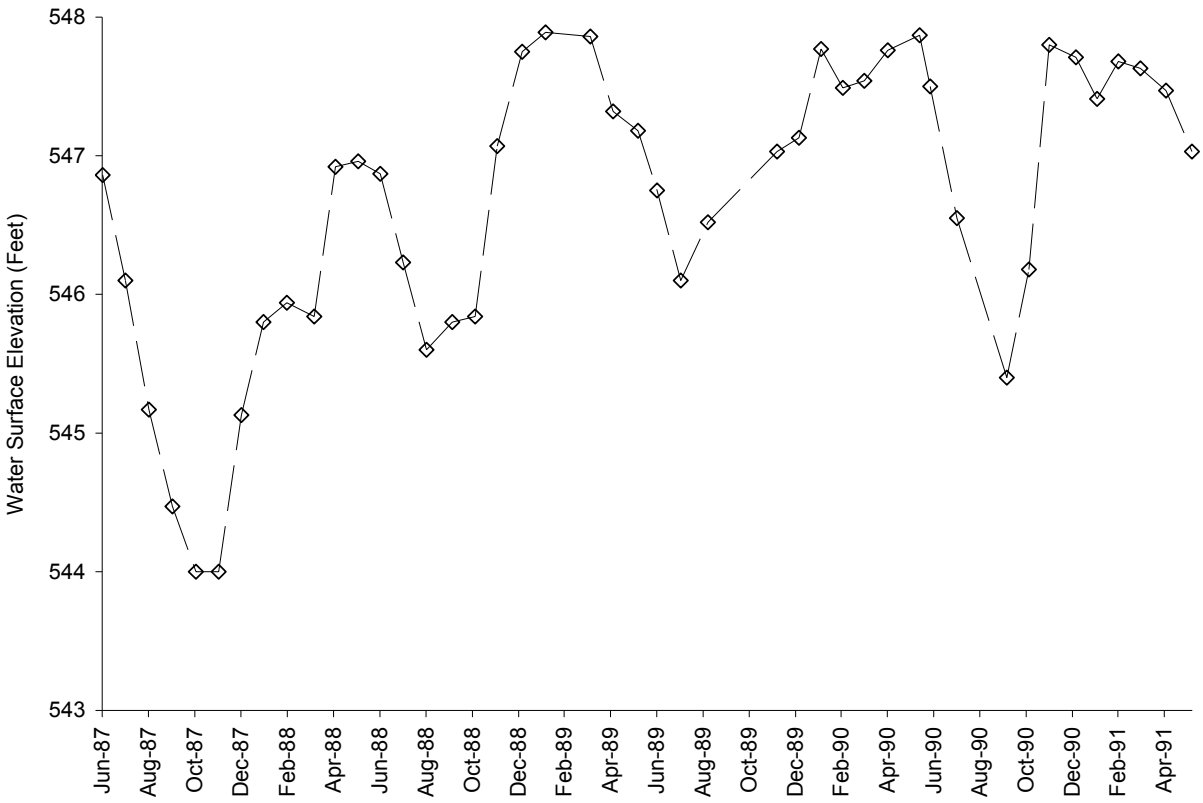

Figure 23. Water surface elevations at wetland BBC-52 (1987-1991).
All data are pre-UPD development.

The mean June 30 monitoring level is 547.2 feet, which is 0.61 feet above the target level, exceeding the threshold criteria (Table 16). The winter median level was within the threshold criteria of a 0.5-foot rise over the modeled predevelopment median. The calculated summer median exceeded the threshold criteria by 0.69 feet. The gage datum should be surveyed for more accurate comparison to the baseline monitoring data peak level targets.

Table 16. Winter and summer median and June 30 mean water levels (ft) at wetland BBC-52.

	Winter Median	Summer Median	June 30 Mean
Target level	547.67	546.6	546.59
Monitoring result	547.54	547.29	547.2
Difference	-0.13	0.69	0.61
Threshold	0.5	0.25	0.25

EC-61

EC-61 is a scrub-shrub wetland that is hydraulically controlled by old beaver dams and abandoned logging roads. Monitoring began in March 2002. An existing staff gage was used to determine wetland elevation. The AquaRod level recorder failed in 2005 and was replaced. An adjustable "beaver deceiver"[41] was installed to control the wetland level.

[41] A flow-control device that is intended to facilitate the retention of beavers while reducing the likelihood of flooding.

Figure 24 shows the effect of the hydraulic control on water levels when the wet season commences. The winter peak levels exceeded the modeled peaks by about 0.2 feet; however, the change is within the allowable increase. The wetland level can rise over 1 foot in less than a week once the wetland level spills into the control structure. Figure 25 shows the predevelopment wetland elevation data for comparison.

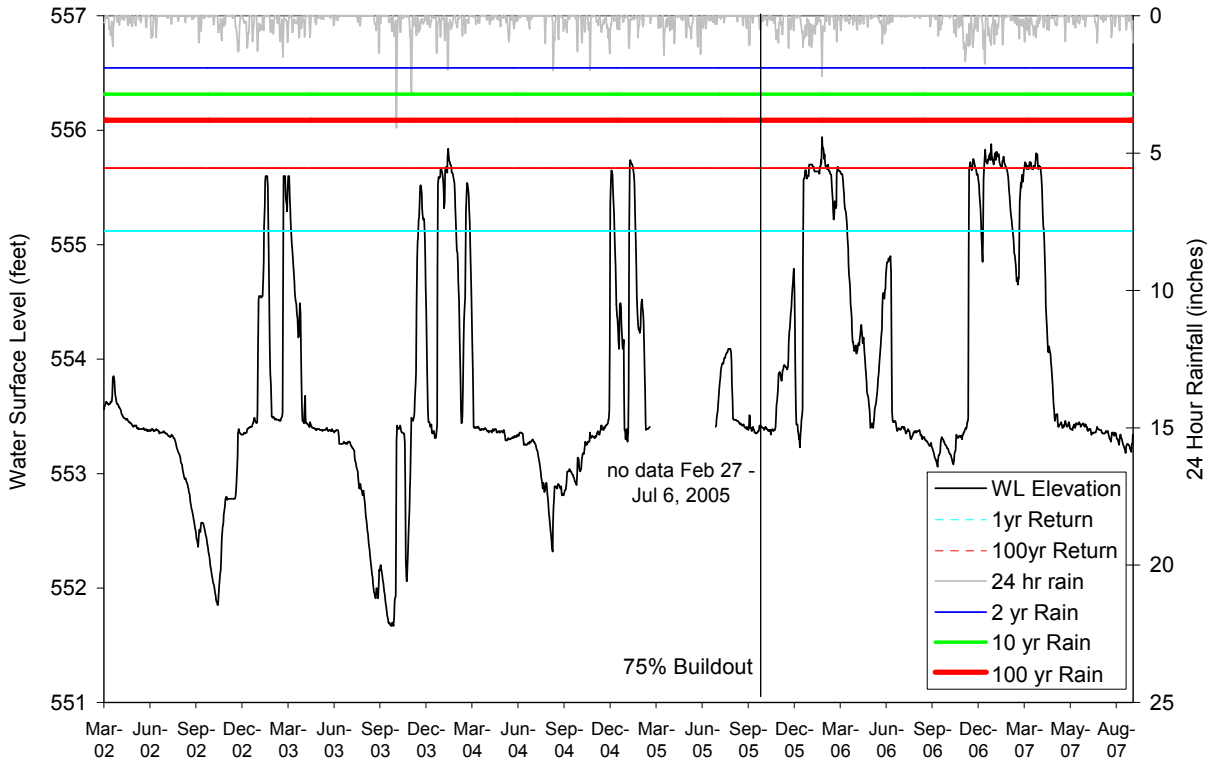

Figure 24. Water surface elevations at wetland EC-61 and daily rainfall totals (2002-2007).
UPD construction began in 2000 and 75% buildout was reached in October 2005 in this subbasin.

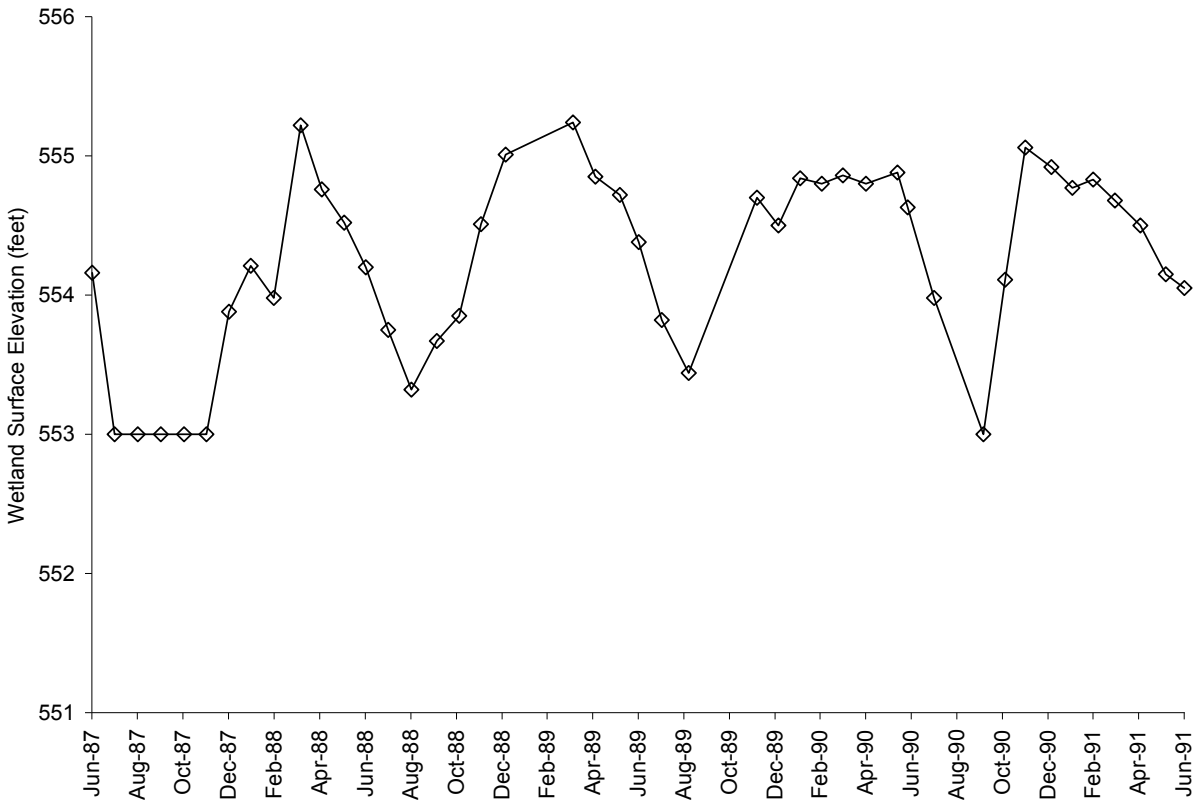

Figure 25. Water surface elevations at wetland EC-61 (1987 to 1991).
All data are pre-UPD development.

The June 30 mean level is 553.4, nearly ½ of a foot lower than the target level and in exceedance of the threshold criteria (Table 17). The winter median level is within the threshold criteria of a 0.5-foot rise over the modeled target. However, the summer median water levels are higher than the target levels by about 0.45 feet, in exceedance of the threshold criteria. The hydraulic control could be adjusted to allow a higher flow rate out of the wetland. This would lower the summer peak levels and spread out the rise to peak wet season levels. If the control is adjusted, monitoring should continue to verify the adjustments are effective.

Table 17. Winter and summer median and June 30 mean water levels (ft) at wetland EC-61.

	Winter Median	Summer Median	June 30 Mean
Target level	555.17	554.09	553.87
Monitoring result	555.1	553.39	553.4
Difference	0.07	0.7	0.47
Threshold	0.5	0.25	0.25

EC-4

EC-4 is downstream of EC-61 and outlets to Evans Creek Central. It is a scrub-shrub wetland with a beaver deceiver and artificial control structure. Monitoring of EC-4 began in March 2002. The water level recorder measured the level in the control structure behind the control orifice.

The baseline monitoring site was not found and the outlet structure elevation is not available. The level recorder failed in April 2006 and was not replaced.

The wetland was dry at the monitoring point for months each year during the predevelopment monitoring (Figure 26) and similar drying occurred in the 2002-2006 post-construction monitoring period including dry June 30 readings where data are available (Figure 27). The modeled target peak return levels ranged from 545 for the 1- year return to 547 for the 100 year. Peak wetland levels cannot be verified relative to these modeled predictions until the outlet structure elevation is determined. The observed annual fluctuations are within the same range as the baseline observations. The beaver deceiver effectively moves water through and the control structure moderates peak levels. The monitoring data indicate the structural controls are functioning correctly.

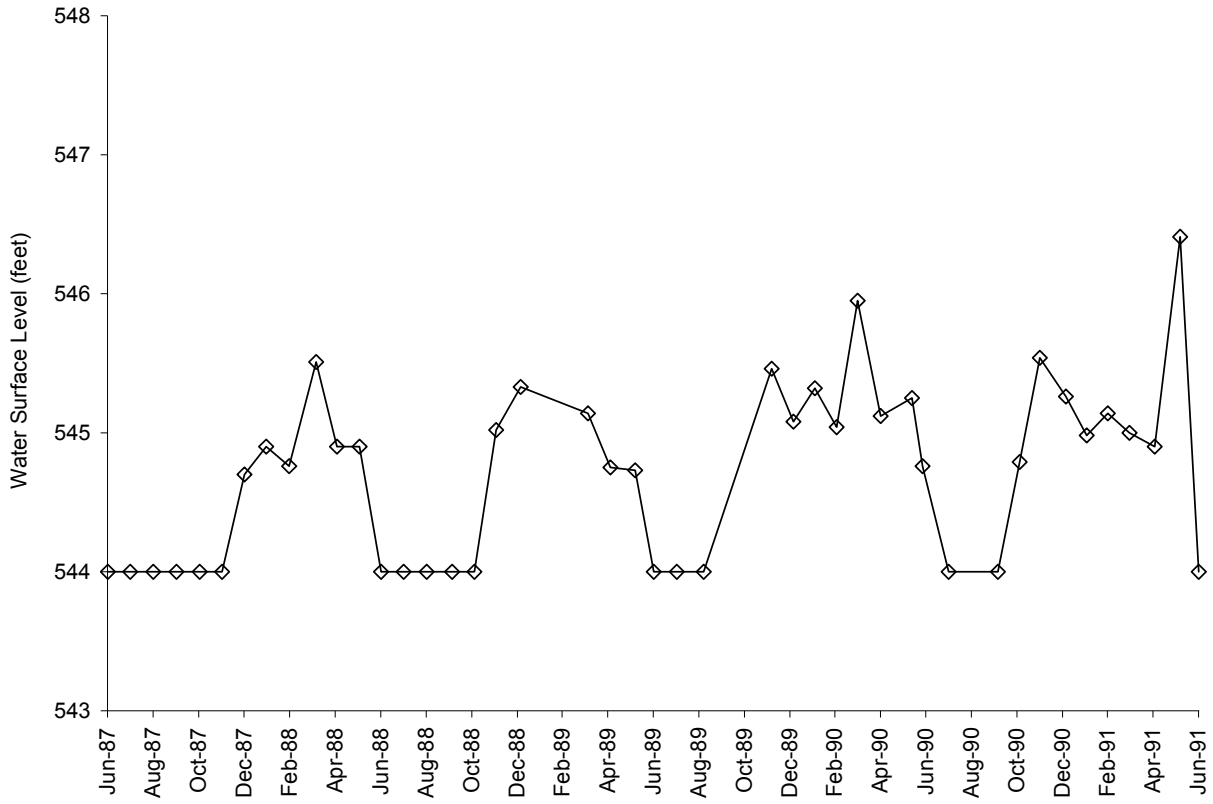

Figure 26. Water surface elevations at wetland EC-4 (1987 to 1991)
All data are pre-UPD development.

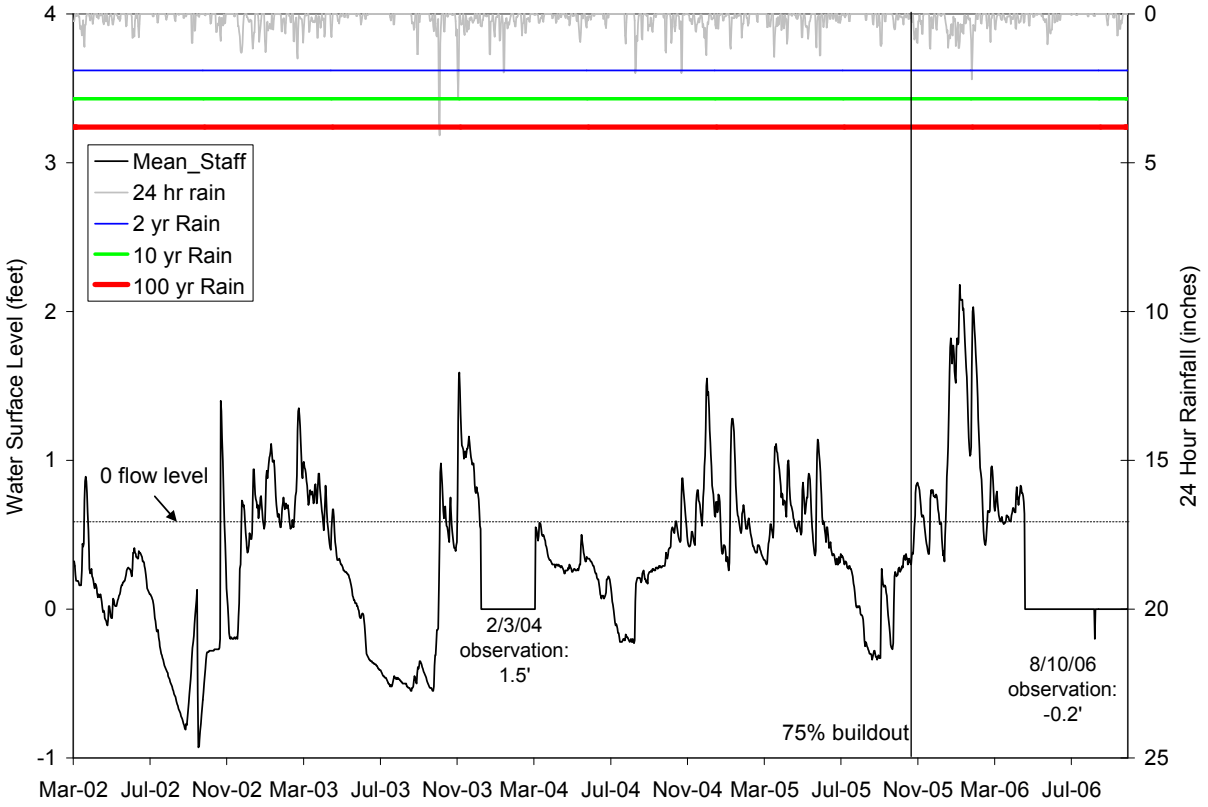

Figure 27. Water surface elevations at wetland EC-4 and daily rainfall totals (2002-2007).
UPD construction began in 2000 and 75% buildout was reached in October 2005 in this subbasin. The wetland is extensively dry at the 0 feet level. No data available 12/25/03 - 3/17/04 and 4/23/06 onward.

EC-3

EC-3 is the receiving wetland for the Evans Creek West drainage and flows into Rutherford Creek. The north lobe of the wetland is separated from the south section by a private road berm. The outlet from the north lobe is a multiple orifice control structure in a manhole built into the road berm. A broad dip in the road is the overflow. The structure does not show up on the inventory of County drainage facilities. The series of wetlands downstream of the road are controlled by beaver dams and other old berms. Monitoring began in May 2002 at the site of the baseline monitoring performed in 1992-1993. The existing equipment was restarted and an AquaRod level recorder was also installed in May 2002. All the recording equipment was inundated and damaged by unexpectedly high water in January 2004 from a failed beaver dam. The damaged AquaRod was replaced with a data logger and water level instrument from existing WLRD inventory in March 2004. That equipment started failing in May 2007, after which there are periods of missing or poor records. An existing staff gage in the wetland, presumably installed for baseline monitoring, is inscribed with elevation numbers. The numbers on the staff plate were used to determine wetland elevation.

The 2-year return target level is almost 4 feet higher than the 1-year level at EC-3 (Figure 28). The wetland exceeded the 1-year level routinely but only exceeded the 2-year target on one occasion when a sudden release of impounded water increased the water level over three feet in a day in January 2004. Baseline data are plotted in Figure 29 for comparison.

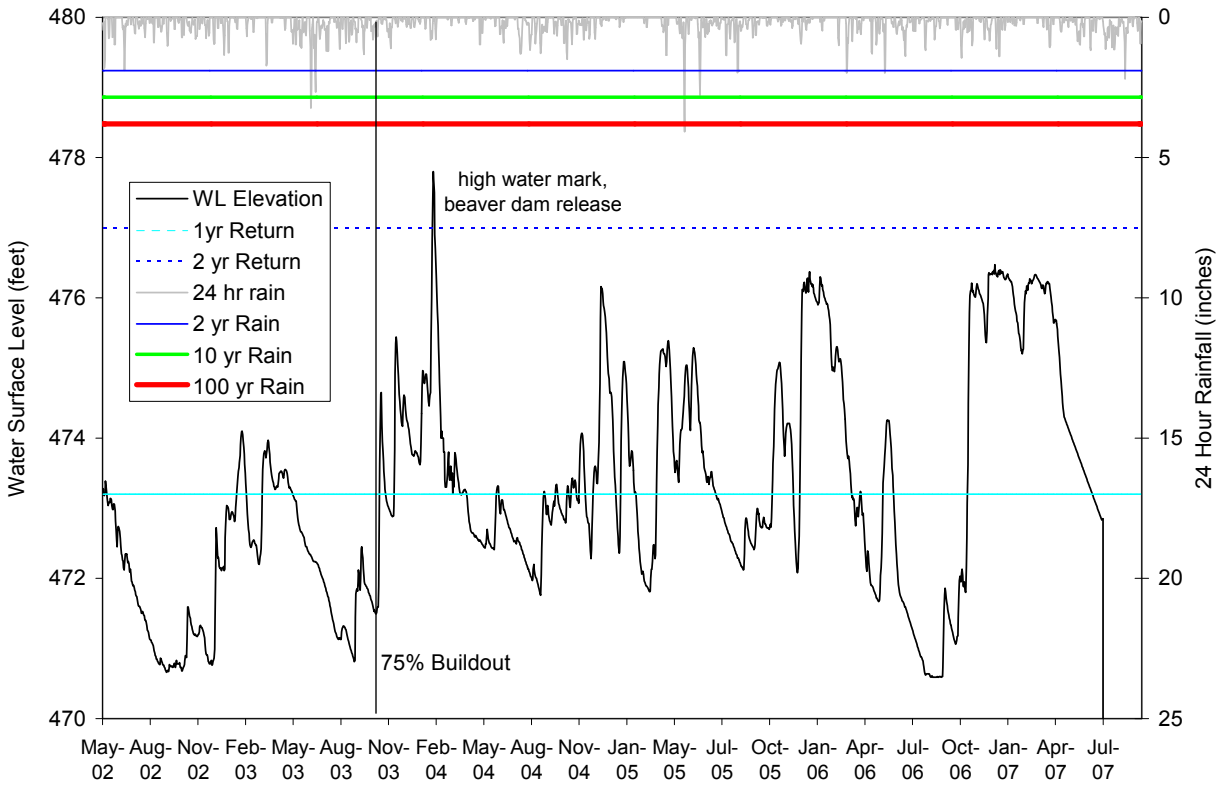

Figure 28. Water surface elevations at wetland EC-3 and daily rainfall totals (2002-2007).
UPD construction began in 1999 and 75% subbasin buildout was reached in October 2003.

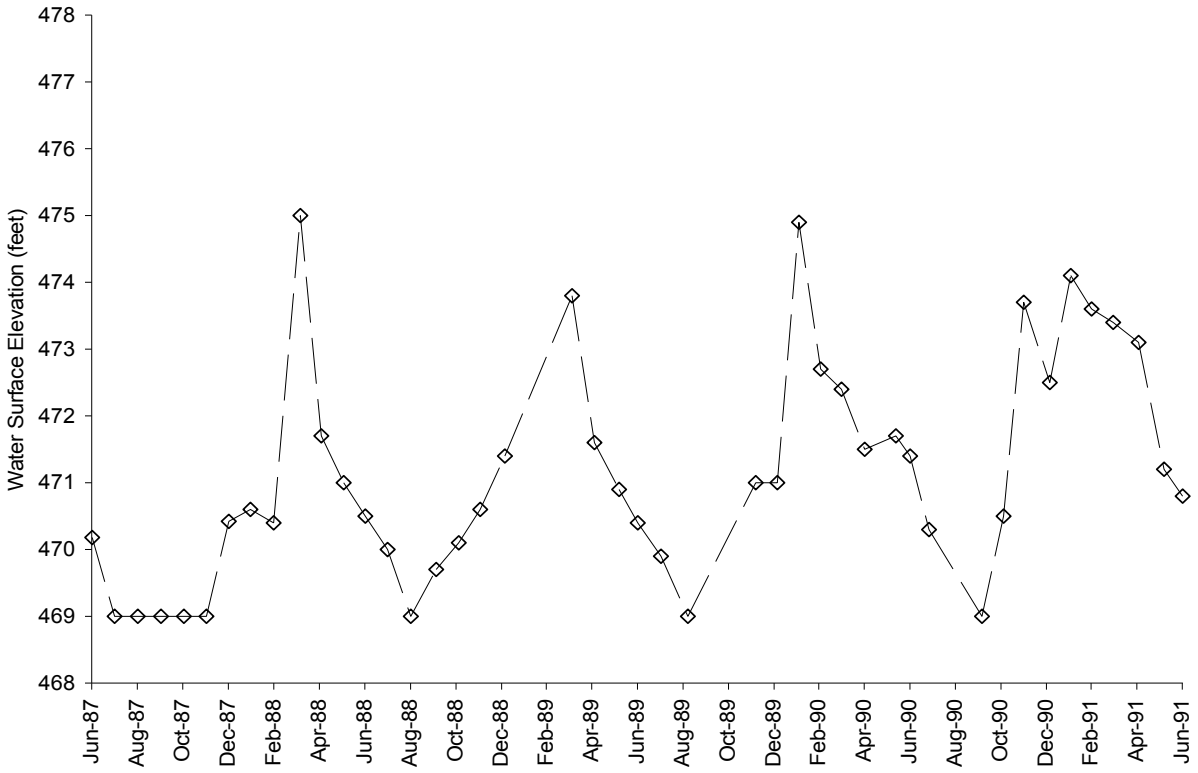

Figure 29. Water surface elevations at wetland EC-3 (1987 to 1991).
All data are pre-UPD development.

The median seasonal wetland levels have exceeded the targets as shown in Table 18. Both winter and summer median levels exceeded the target by over 2 feet. The June 30 mean exceeded the target by 1.6 feet. Starting in December 2005 and continuing in 2006-2007, this wetland sustained high water in the winter period that affected the winter median. The levels were about 1 foot below the 2-year target peak.

Table 18. Winter and summer median and June 30 mean water levels (ft) at wetland EC-3.

	Winter Median	Summer Median	June 30 Mean
Target level	471.80	470.5	471
Monitoring result	474.2	472.8	472.6
Difference	2.4	2.3	1.6
Threshold	0.5	0.25	0.25

It is likely that the outlet from the wetland has been altered in some way to retain water at a higher level. A WLRD engineer looked at the structure in April 2007. The water level was near the top of the stand pipe and flowing through an elbow near the top of the structure. If there is a lower orifice it may be plugged, preventing water release at lower levels. Peak flows at the Rutherford Creek gage did not show an effect from the elevated EC-3 north lobe levels, but there is an indication that winter and spring baseflow is elevated.

No corrective actions are suggested other than investigating the outlet structure from the north lobe. Ownership of the structure should be determined and the structure examined to see if there

is a plugged orifice. Continuous monitoring is scheduled for completion in 2009; however, WLRD should continue monitoring wetland level until the elevated water levels are corrected.

BBC-UN1

BBC-UN1 drains to the MC-4 stormwater facility. The wetland was not modeled for post-development targets. Flow out of the wetland level is controlled by a v-notch weir and six inch diameter orifice located in an underground utility box. Continuous water level monitoring equipment was installed and operated by the developer from 1998 through 2001 to assess the performance of the MC-4 facility. WLRD took over the equipment in 2005. The existing equipment failed and was replaced in late 2005.

Peak water levels during the current monitoring period (Figure 30) are approximately 1.5 feet higher than during the baseline monitoring (Figure 31). The wetland goes dry every summer. The dry period does not appear to be different from levels during the baseline monitoring. The baseline observations showed the wetland level would go from dry to 3 feet of depth within one month, usually between early November to early December. The continuous monitoring data show a similar rise, but the continuous data set shows the wetland can elevate 2 feet in a week[42].

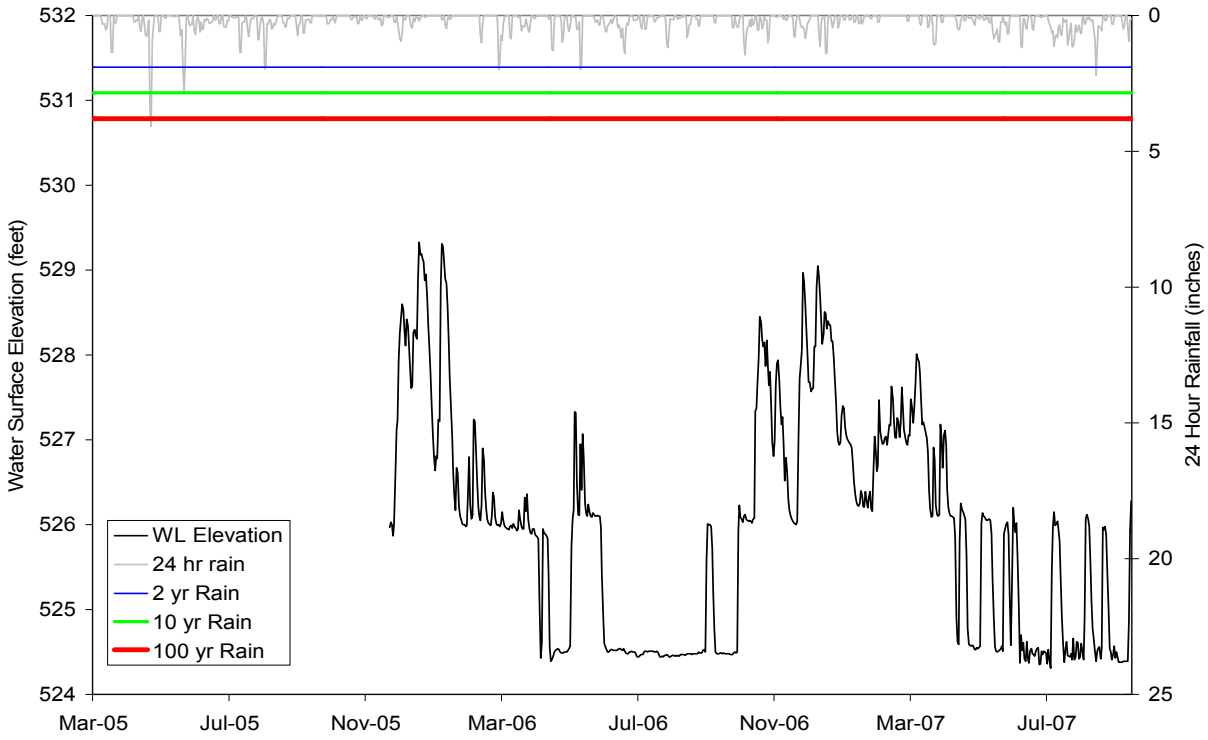

Figure 30. Water surface elevations at wetland BBC-UN1 and daily rainfall totals (2005-2007).
BBC-UN1 is located within the Mackey Creek subbasin where UPD construction began in 1998 and 75% buildout was reached in September 2001.

[42] In addition to water level, a record of discharge from the BBC-UN1 is available. Peak discharge was less than one cubic foot per second (cfs) and the mean daily discharge for 2006 and 2007 was 0.12 cfs.

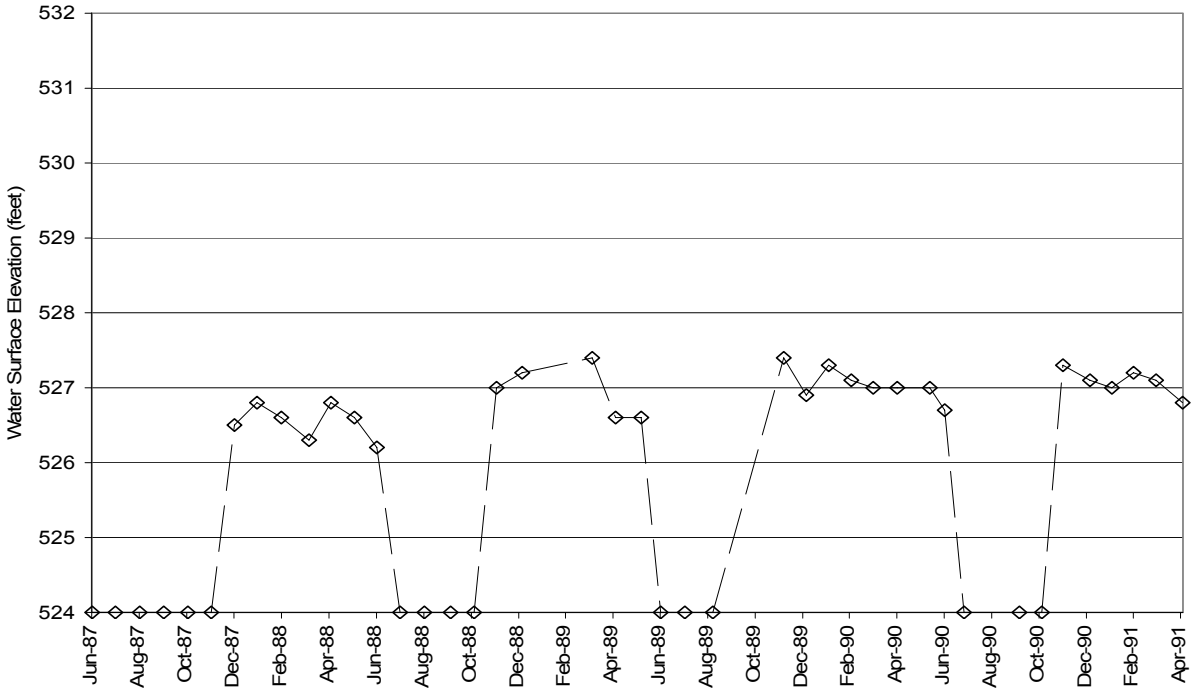

Figure 31. Water surface elevations at wetland BBC-UN1 (1987-1991).
All data are pre-UPD development.

No corrective actions are recommended for BBC-UN1.

Threshold Exceedance Criteria and Evaluation

Comparison to the threshold criteria is made in the discussion of results for each monitoring location (see previous section), but a summary is presented in Table 19.

Table 19. Summary of wetland hydrology relative to four threshold exceedance criteria.
Current monitoring results compared with predevelopment data. Bolded italics indicate thresholds were exceeded.

Wetland	<1' increase max annual level	Difference Predevelopment vs. Current Monitoring		
		Winter Median (0.5' Threshold)	Summer Median (0.25' Threshold)	June 20 Mean (0.25' Threshold)
Trilogy				
BBC-44	No	0.14	0.13	0.04
SR-24B	No	***0.56***	***1.27***	***1.21***
SR-24A	N/A	***0.54***	***0.62***	***0.40***
SR-24C	N/A			
BBC-45A	No	***- 0.61***	-0.14	***0.51***
BBC-26	No			
Redmond Ridge				
BBC-45	No	-0.24	0.12	***0.58***
BBC-52	No	-0.13	***0.69***	***0.61***
EC-61	No	0.07	***0.7***	0.47
EC-4	No			
EC-3	***Yes***	***2.4***	***2.3***	***1.6***
BBCUN-1	N/A			

Corrective Actions

No corrective actions are recommended pending additional investigations and data collection as summarized in Table 20.

Table 20. Summary of actions recommended for wetland hydrology.

Location	Recommended Action
SR-24A & SR-24B	Investigate cause of elevated summer levels
BBC-26	Evaluate summer water levels in 2008-2010 report
BBC-45	Survey gage datum
BBC-52	Survey gage datum; investigate cause of elevated summer levels
EC-61	Consider with technical staff whether adjustment to outlet control is necessary to lower summer water levels
EC-4	Survey outlet structure to verify water surface elevations
EC-3	Investigate outlet control structure for cause of elevated summer water levels
BBC-44, BBC-45A, BBC-UN1	No recommendations

3.7 Stream Hydrology

In 1988, King County Surface Water Management Division (now Water and Land Resources Division, WLRD) established stream gages in the UPDs to provide baseline and calibration hydrologic data for the development of hydrologic models used to design the UPD stormwater controls. Data collection was discontinued in 1994.

Monitoring for the current 'post-development' monitoring period began between 1998 and 2005 depending on the site (see Table 21)[43] at the same locations used for predevelopment monitoring where applicable. The Trilogy monitoring plan calls for continuous streamflow monitoring at five streams [Colin Creek North (02C), Colin Creek South (02D), Adair Creek (53A), Wallace Creek West (53B), Wallace Creek North (53C)] and two bypass gages: [Adair Creek Bypass (53D) and Wallace Creek Bypass (53F)] (King County 2001). The Redmond Ridge monitoring plan calls for continuous streamflow monitoring at two streams: Rutherford Creek (18F) and Evans Creek Central South Weir (18B) (King County 1999). See Appendix K for stream hydrology sampling schedule through 2007.

[43] In 1998, WLRD began to reoccupy the monitoring sites to prepare for post-development monitoring. From 1998 to summer 2000, five sites were monitored with the assistance of University of Washington students. The data were used for the student's research and to assess the feasibility of monitoring continuous turbidity at the gage sites. The data for that period were lost or are unusable. Therefore, Adair Creek is the only gaging record presented from 1998 onward.

Table 21. Stream gage monitoring dates for pre- and post-development monitoring periods.

Site Code	Site Name	Predevelopment		Post-development
		Begin	End	Begin
Trilogy				
02B	BBC-45a Outlet	10/1/1988	6/9/1994	not monitored
02C	Colin Creek North	4/10/1990	6/24/1994	9/11/2000
02D	Colin Creek South	4/11/1990	6/28/1994	9/20/2000
53A	Adair Creek	4/11/1990	6/28/1994	3/5/1998
53B	Wallace Creek West	4/10/1990	6/29/1994	10/24/2000
53C	Wallace Creek North[44]	6/7/1990	6/29/1994	3/25/2002
53D	Adair Creek Bypass	Post-development only		5/1/2003
53F	Wallace Creek Bypass	Post-development only		3/22/2005
Redmond Ridge				
18F	Rutherford Creek	not monitored by King County		10/4/2001
18B	ECC South Weir	10/1/1988	6/8/1994	10/1/2000
18C	ECC Central Weir	1/15/1990	5/22/1994	not monitored

The overall goal of the post-development hydrologic monitoring is to determine if there are unexpected changes in the hydrology of the streams and wetlands as a result of UPD construction and development. A complex system of stormwater controls is built into the development to maintain the hydrologic response of the streams at their predevelopment condition. The post-development monitoring is intended to assess the hydrologic performance of the streams compared to their predevelopment condition. A threshold of 20% change in storm peak magnitude and flow durations was set as a threshold for corrective action. In addition, both monitoring plans call for an assessment of the duration and linear extent of channel drying (King County 1999, 2001).

Modifications

Channel drying is assessed only at the gaging locations and linear extent is not assessed due to the time consuming nature of property access permission and the lack of similar predevelopment data. No other modifications to the monitoring plans (King County 1999, 2001) have occurred.

Sampling recommendations – No sampling changes are recommended.

Procedures

Continuous streamflow is determined by measuring water level, or stage, behind a natural or artificial hydraulic structure and applying a specific discharge to each discrete water level with a stage-discharge rating table. The rating table is derived from standard equations for flow through flumes, weirs, and culverts, and direct measurements of discharge at each site. Water level is measured with electronic instruments and data loggers. All of the original monitoring equipment installed at each monitoring site eventually failed at some point during the monitoring period and required replacement. Gaps in the data record because of equipment failure, particularly in 2007, are discussed below for each monitoring site.

[44] Wallace Creek North has been referred to as Wallace Creek East in the past.

Data sets were prepared using database routines developed by WLRD staff. Data are stored and are available for download in the King County Hydrologic Information Center database (link[45]). Documentation of the data set preparation is stored in hard copy files.

Results

The streamflow data are presented by gaging station with an analysis of peak flow comparing daily peaks with the target peak flows for 2-year, 10-year, and in some cases 100-year return period storms derived from modeling (Northwest Hydraulic Consultants Inc. 1994, Otak Incorporated 2007). Flow durations are calculated from hourly gage data for three years (water years 2004-2006[46]) and are plotted with the modeled duration curves for comparison (Otak Incorporated 2007). The target is for the gaged flow curve to be at or below the modeled curve. A more accurate assessment of the duration performance will be made by running the pre- and post-development models with the actual local rainfall for all the years being analyzed. The results of that analysis should be available in time for the 2008-2010 monitoring report. Comparison of the 2004-2006 flow durations with the modeled post-development flow durations may indicate where the stormwater controls are not meeting expectations.

Trilogy

Northeast Drainage: Adair Creek and Adair Creek High Flow Bypass (Gages 53A and 53D bypass)

Flow from Adair Creek is measured in a 2-foot H-flume that was installed in 1990 for baseline monitoring. Flow monitoring commenced March 5, 1998. A large tree fell on the gage in December 2006 and caused damage that took until May 2007 to repair. No flow data are available for that period. At various other times equipment malfunction led to loss of data. Where appropriate, mean daily discharge is estimated from rainfall and gage data from other nearby sites. Peak flow data is not estimated unless informed by a crest-stage reading or high water marks. A new water level recorder was installed in 2008. Based on the gage data for Adair Creek, the stormwater facilities are meeting the criteria for regulating peak flows (Figure 32).

[45] http://green.kingcounty.gov/wlr/waterres/hydrology/

[46] These three years (2004-2006) represent typical rainfall years and also have generally complete gage records. Water year 2007 is omitted due to the high frequency of equipment malfunctions.

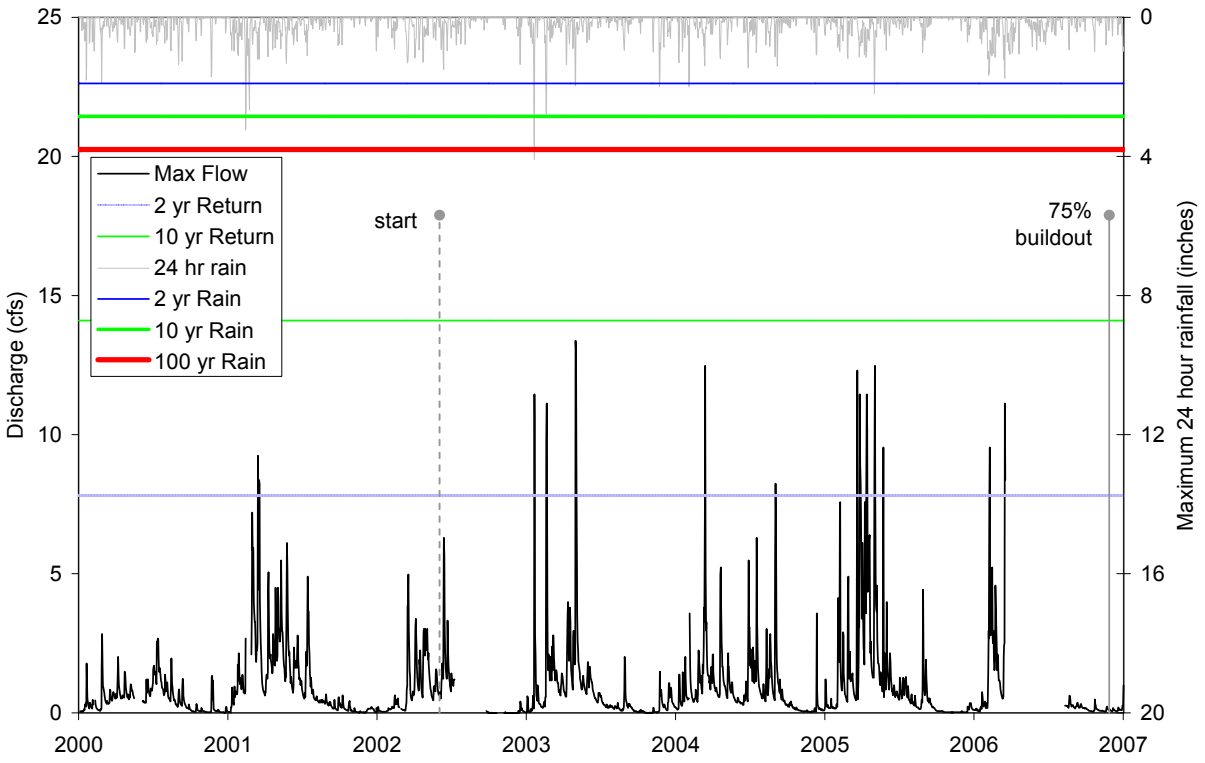

Figure 32. Maximum daily flow at the Adair Creek gage (53A) from 1998-2007.
Includes maximum daily rainfall totals. Construction began in 2002 and 75% buildout was reached in September 2007 in the Adair Creek basin.

Based on the plot of the flow duration curve for 2004-2006 (Figure 33), it is possible that Adair Creek flow durations are greater than the predevelopment modeled durations by about 40% for flows less than 10 cfs. The HSPF model will need to be run with the rainfall for the gaged period to verify the exceedance.

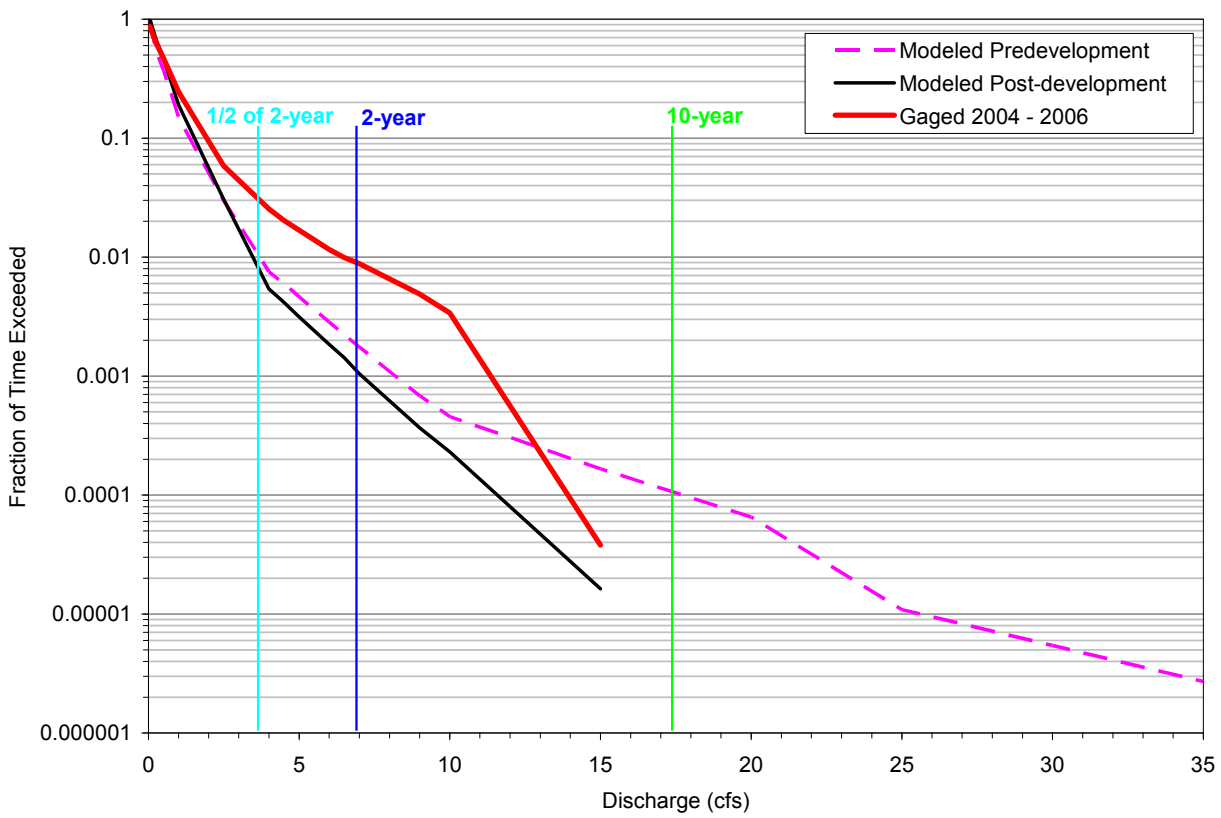

Figure 33. Flow duration curve for Adair Creek (53A) for 2004-2006.

Adair Creek was dry at the gage in 2003 for over 60 days and for 10 days in 2004. The creek went dry at the gage for at least 10 days in each of the summers of 1990, 1991, and 1992.

Monitoring of the Adair Creek high flow bypass (53D) began May 1, 2003. Flow is conveyed through a pipe to an energy dissipating structure below West Snoqualmie Valley Road. Flow from the bypass spills over a 10-foot-wide concrete weir and is conveyed in a channel to the Snoqualmie River. Rate of flow is determined by measuring water level behind the weir and converting the level to discharge with a rating table. The width of the weir makes changes in water level insensitive to changes in flow, and the surging nature of the water level during high flows creates inaccuracy in the measurement of water level. The Snoqualmie River backed up the channel in January 2006 and flooded the structure. The recording equipment worked sporadically after the inundation. The water level recording equipment failed in October 2006, and no data for the 2007 water year are available. A new sensor and recorder was installed for the 2008 water year.

The effectiveness of the bypass in reducing peak flows varied with different storm events (Figure 34). During the intense May 31, 2005 cloudburst, the peak flow was approximately 18 cfs at the bypass and about 5 cfs at the creek. Generally, the bypass took a high percentage of the peak flows from spring and summer storm events. During winter flows, when peak flows at the creek gage exceeded 10 cfs, the bypass peak flow would be 2-3 cfs.

During the periods when both the bypass gage and the creek gage were functioning, the bypass conveyed about 25 percent of the combined flow. During summer low flow periods, the bypass conveyed more flow than the creek channel. When the creek went dry at the gaging location, the bypass continued to maintain a small flow.

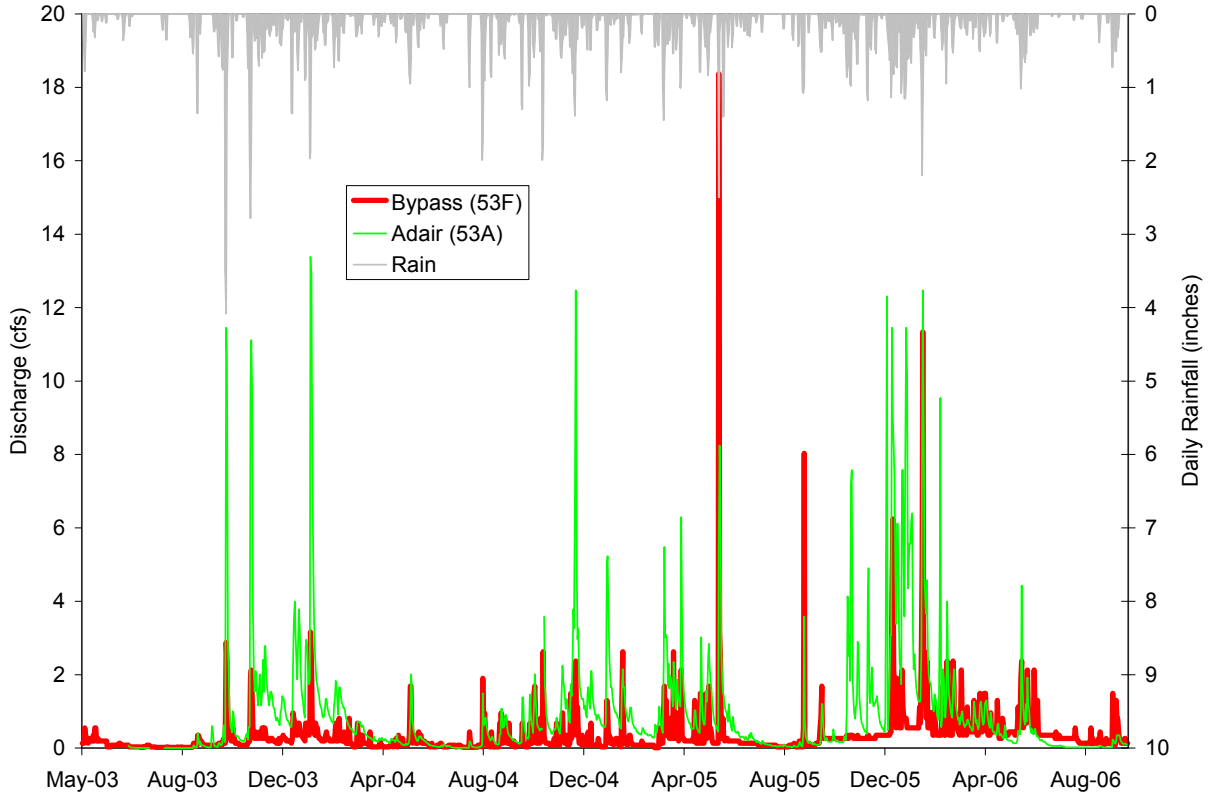

Figure 34. Maximum daily flow for Adair Creek (53A) and Adair Creek bypass (53D).
Includes maximum daily rainfall totals.

The Adair Creek channel went dry for 60 days in 2003 and 10 days in 2004 while the bypass continued to have flow. It is not know if the flow in the bypass would show up in the creek channel if not sent down the pipe. The Adair Creek bypass is a system of flow splitters at seven detention ponds. They work in conjunction with four other detention ponds to achieve the flows predicted by the post-development modeling.

The Adair Creek basin reached 75% buildout in September 2007 which is at the end of this reporting period.

<u>Southeast Drainage: Wallace Creek West, Wallace Creek North, and Wallace Creek High Flow Bypass (Gages 53B, 53C, and 53F bypass)</u>

Flow from Wallace Creek West is measured in a 1.5 foot H-flume installed in 1990 for baseline monitoring. The current flow record starts in October 2000 when WLRD took over data

collection[47]. During high flow events, water impounds behind the culvert under 244th Avenue NE[48] enough to flood the flume. The flume was moved in the summer of 2002 to an upstream location above the impounded water level[49]. In 2005, the recording equipment started to fail. There are significant gaps in the flow record for June 2005 through December 2006.

Peak flows for Wallace Creek West (53B) never exceeded the 10-year target (Figure 35). 2-year target flows were exceeded during 2-year intensity storms or large multi-day events.

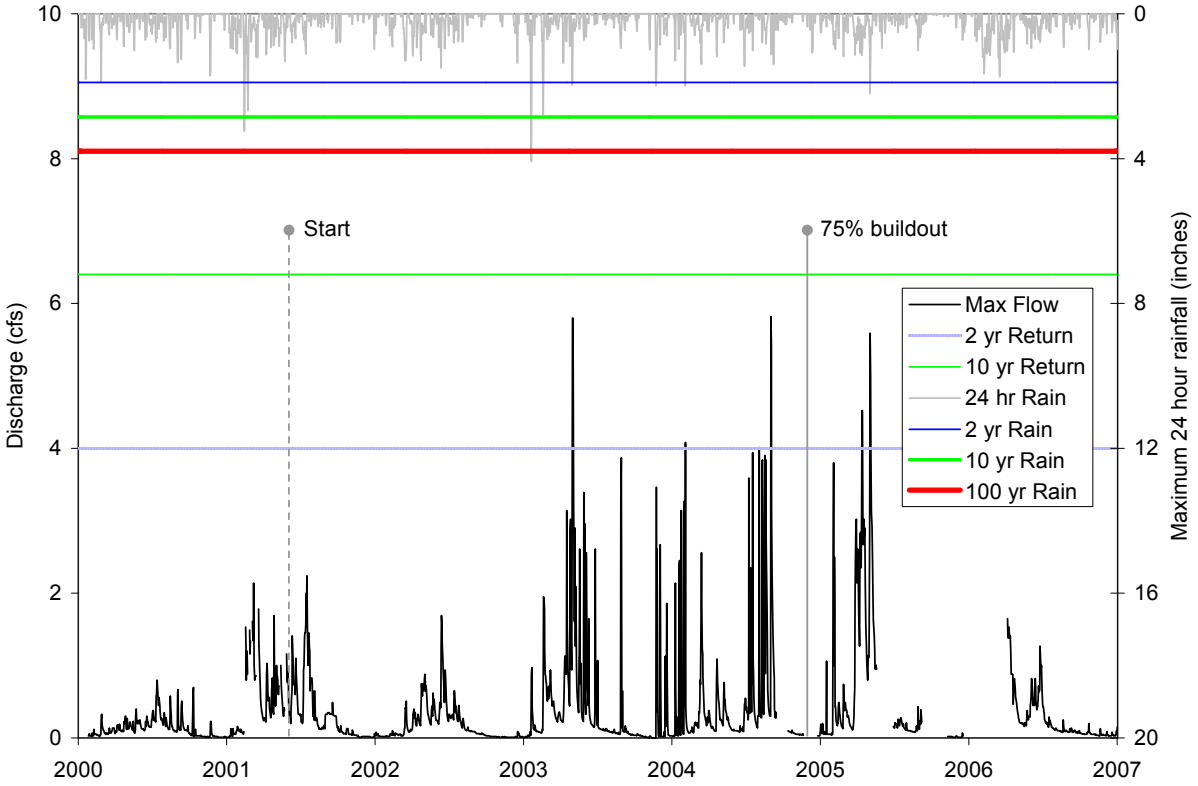

Figure 35. Maximum daily flow at the Wallace Creek West gage (53B) from 2000-2007.
Includes maximum daily rainfall totals. Construction began in 2001 and 75% buildout was reached in September 2005 in the Wallace Creek basin.

Based on the flow duration plot for 2004-2006[50] (Figure 36), the flow durations are less than 20 percent greater than the predevelopment modeled durations and less than the predevelopment modeled durations for flows greater than the 5-year return flow. The HSPF model will be run with the rainfall for the gaged period to verify this conclusion; however, modeling results were not available at time of writing.

[47] Flow monitoring commenced February 27, 1998, with University of Washington students performing field data collection. However, these data were lost or unusable.
[48] The culvert under 244th was replaced in 2008.
[49] Prior to relocating the gaging station, the flume was affected by the impoundment for 22 days in water year 2002.
[50] The hourly gage record was estimated for some periods during the spring and summer of 2006, but rainfall was light and the flows were 1 cfs or less.

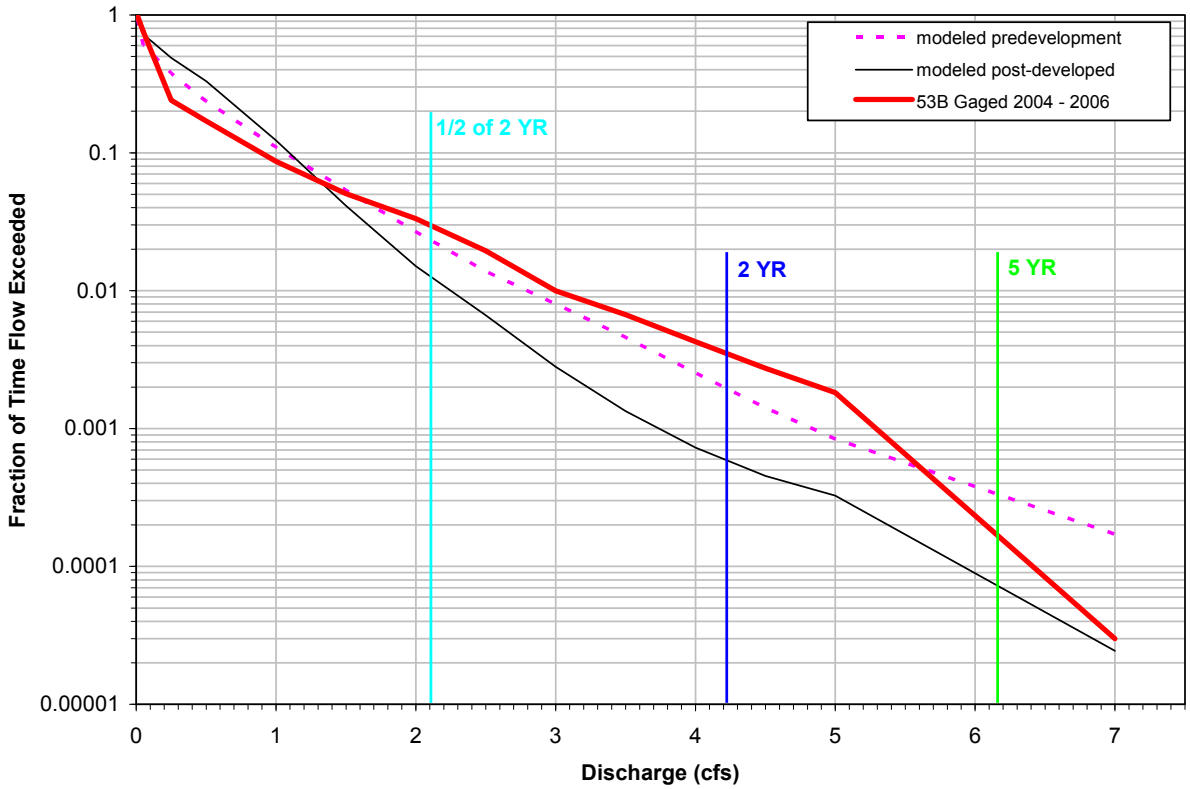

Figure 36. Flow duration curve for Wallace Creek West (53B) for 2004-2006.

Monitoring of the Wallace Creek bypass began March 22, 2005. Flow is conveyed through a pipe system to an energy dissipater below West Snoqualmie Valley Road. Flow in the pipe system is shallow with high velocity, and these characteristics make flow difficult to measure. A manhole[51] in the system above the SED 1 stormwater facility was chosen to measure flow. Overflow from the facility is conveyed to the bypass, so any of that flow was not measured. The access basin is close to the surface, and the pipe slope is relatively flat. An expanding pipe ring was fitted to the 36-inch diameter bypass pipe and an Isco 4230 bubbler used to measure water level in the pipe. This expensive flow meter was provided to the project from the stock of instrumentation for the WLRD stormwater monitoring program. It allows accurate measurement of water level in shallow water with minimal presence in the flow cross section. The instrument requires significant power resources, and data were lost at times when the battery died but had not yet been replaced because of WLRD staffing reductions in the gaging unit. A series of direct measurements of discharge in the pipe were used to create a relationship between water level and flow. The flow record for 53F is based on the measured water level in the pipe and the corresponding discharge from the rating curve.

The flow data for bypass gage 53F show that the bypass collected most of the peak storm flows and, in some cases, nearly all of the flow above baseflow (Figure 37). In the reporting period, the bypass gage had 4 days with a peak flow of over 10 cfs. The stream gage (53B) maximum

[51] This manhole was noted as BPUN-MH 200 in the approved development plans for Trilogy (Otak Incorporated 2001).

instantaneous discharge was 6 cfs during the period. On 46 days, the peak discharge at the bypass was in excess of 3 cfs. The stream gage reported 30 days of peak discharge over 3 cfs.

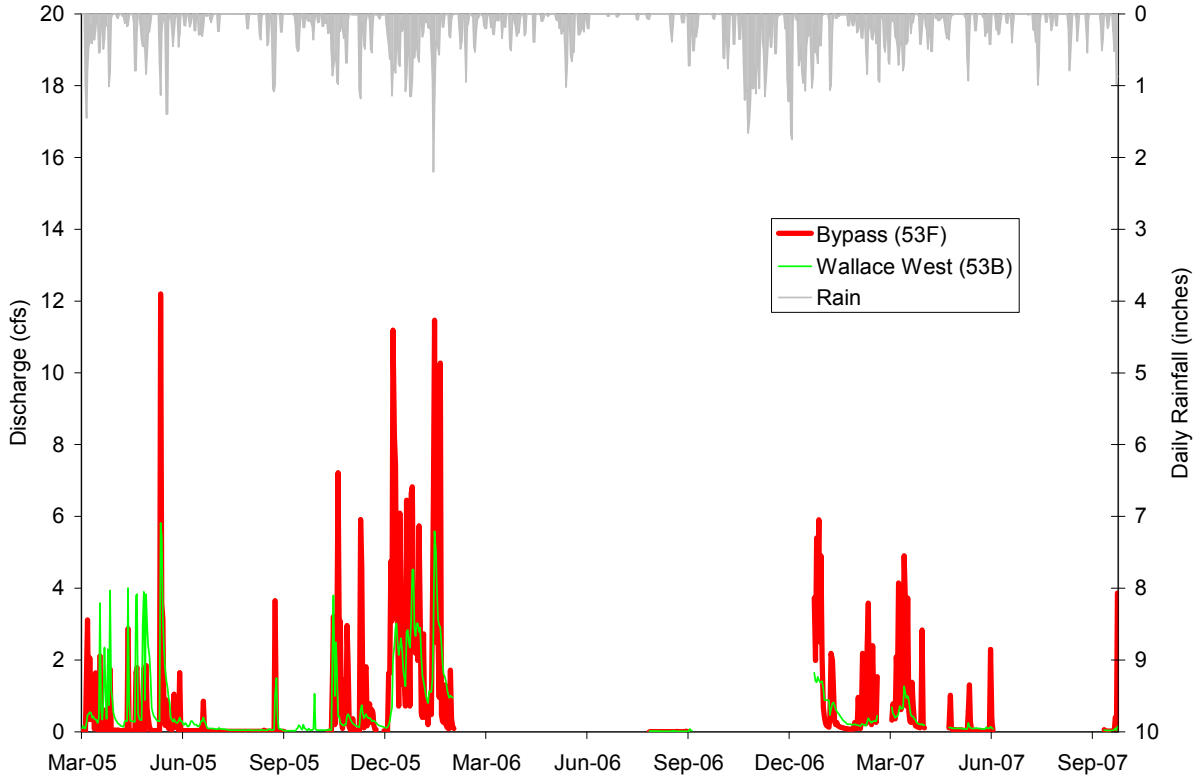

Figure 37. Maximum daily flow for Wallace Creek West (53B) and Wallace Creek bypass (53F).
Includes maximum daily rainfall totals.

During the periods when both the bypass gage and the creek gage were functioning, the bypass conveyed about 40% of the combined flow. Because of the difficulties in measuring discharge at low levels, the gage records are poor during summer low flow periods. However, it appears the creek conveyed more summer base flow than the bypass system. The bypass went dry at the gaging location, whereas the creek retained a small flow.

Based on the peak flow and duration analysis of Wallace Creek West and the data from the bypass gage, it appears the splitter system is functioning as intended. An HSPF model run and continued monitoring will be needed to verify this conclusion.

Wallace Creek North (53C) does not receive flow from any UPD stormwater facilities. It is fed from the SR-24C wetland. No post-development modeling was performed. Post-development flow monitoring began in 2002. Flow is measured in a 12-inch Parshall flume that was installed in 1990 for baseline monitoring. The flume is installed in the ravine upstream of Novelty Hill Road. The slopes are steep and erosive and frequently send rocks into the flume. A large landslide in the ravine buried the flume in 2006. The stream goes dry at the gage site every year in the summer. The level recorder stopped working in 2006. It was replaced in late 2007.

Peak flows at Wallace Creek North are no greater after 2002 than during the 1990-1994 baseline monitoring, and mean monthly flows are comparable (Figure 38). The channel continues to go dry each summer.

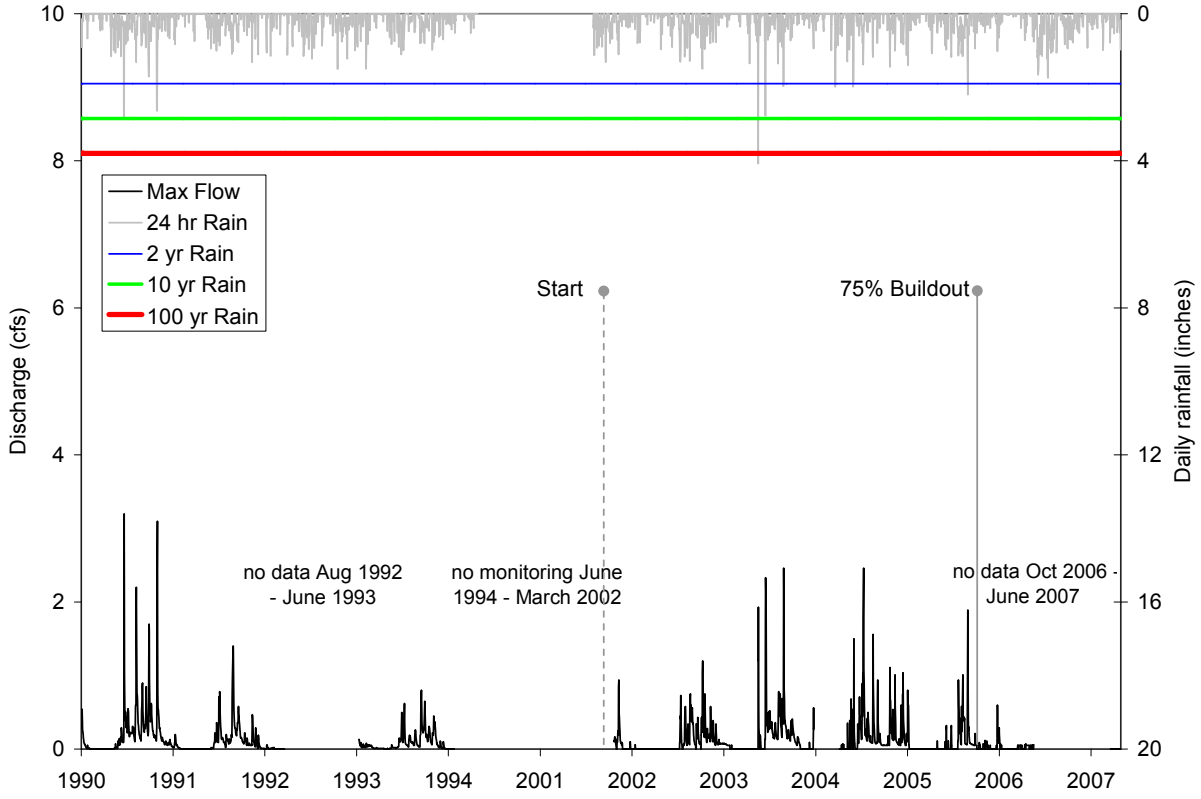

Figure 38. Maximum daily flows at the Wallace Creek North (53C).
Includes maximum daily rainfall totals. Construction began in 2001 and 75% buildout was reached in September 2005 in the Wallace Creek basin.

Northwest Drainage: Colin Creek North (Gage 02C)

Flow from Colin Creek North is measured in a 2-foot H-flume that was installed in 1990 for baseline monitoring. Post-development flow monitoring commenced September 20, 2000. The recording equipment worked for most of the reporting period; however, some flow bypassed the flume in November 2001[52].

The 10-year target flow was never exceeded for Colin Creek North (02C) (Figure 39). Two-year target flows were exceeded during 2-year intensity storms or large multi-day events.

[52] The flume approach was reconfigured with a notch in the wing wall to allow flows in excess of the flume capacity to be conveyed around the flume in a predictable way. The water level at which flow bypasses the flume was determined and the rating table for the flume adjusted to account for the increased flow. Maximum flow for a 2-foot H flume is 11 cfs. Flows of 12 and 13 cfs have been observed during storm events when the bypass is in effect.

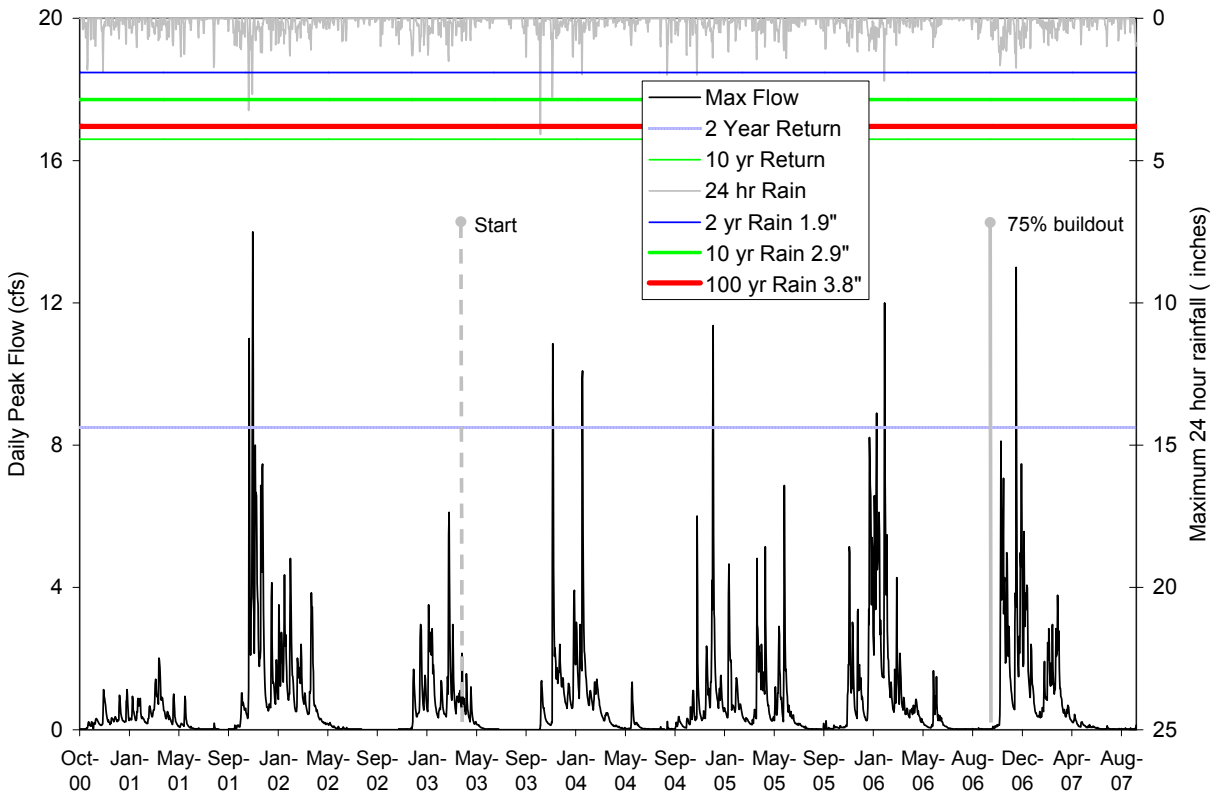

Figure 39. Maximum daily flow at the Colin Creek North (02C) gage.
Includes maximum daily rainfall totals. Construction began in 2003 and 75% buildout was reached in October 2006 in the Colin North basin.

The post-development modeled durations exceeded 4 cfs 1% of the time. Based on the flow duration plot (Figure 40) from 2004-2006, Colin Creek North flow exceeded 5 cfs 1% of the time, a 25% increase. The gaged flows exceeded 10 cfs 0.1% of the time and the modeled post-development modeled flows exceeded 6 cfs 0.1% of the time. For the 2008-2010 monitoring report, the HSPF model will be run with the rainfall data for the gaged period to verify the exceedance.

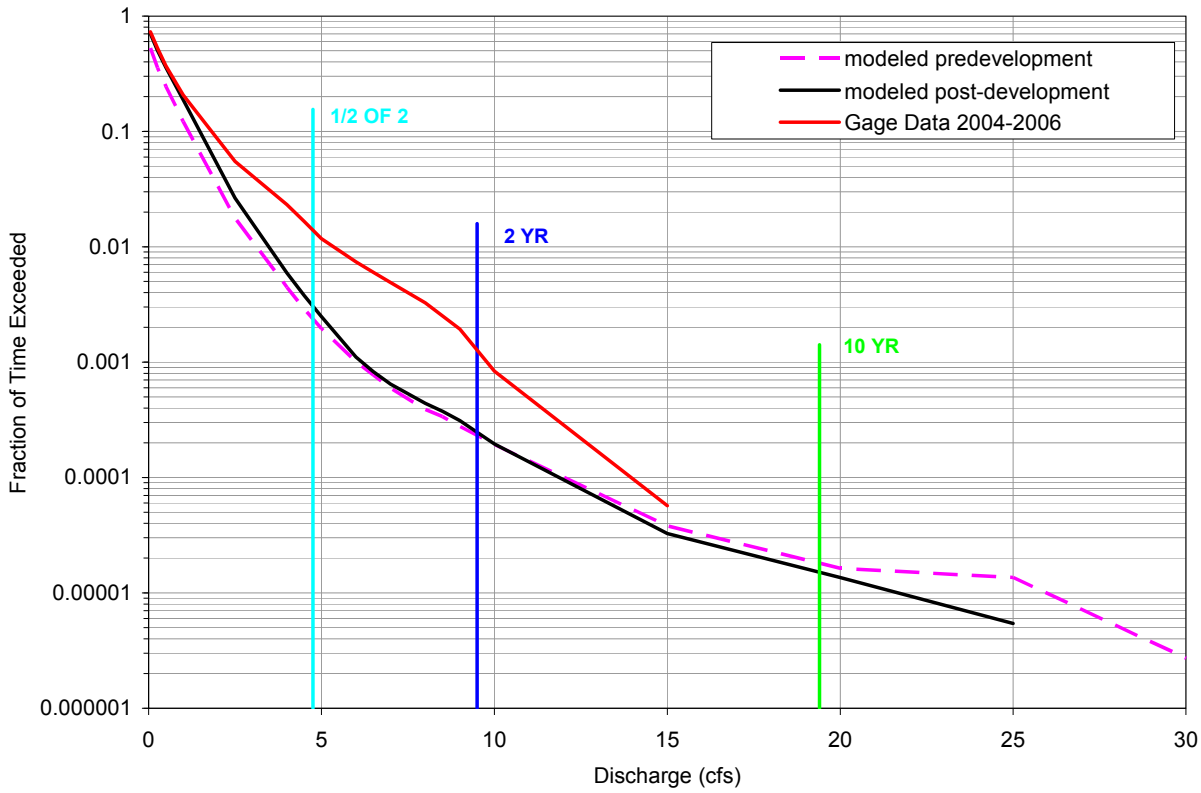

Figure 40. Flow duration curve for Colin Creek North (02C) for 2004-2006.

Colin Creek North frequently goes dry at the gage (02C) (Table 22). The trend toward persistent summer flow is consistent with elevated summer wetland water levels in BBC-26 since 2004.

Table 22. Number of days Colin Creek North goes dry.
Dates are based on the gage record (18B).

Year	Days Dry	Year	Days Dry
1990	60	2001	23
1991	30	2002	90
1992	0	2003	100
1993	0	2004	5
		2005	3
		2006	3
		2007	0

<u>Southwest Drainage: Colin Creek South (Gage 02D)</u>

Flow from Colin Creek South is measured in a 2-foot H-flume that was installed in 1990 for baseline monitoring. Post-development flow data collection began in October 2000. The water level recording equipment began to malfunction in 2005, and as a result the continuous data are of poor quality from September 2005 through February 2007. High flows passed around the flume in November 2003 and December 2004. The continuous flow data are estimated for those periods. Peak flow data are not estimated unless informed by a crest-stage reading or high water marks. A new water level recorder was installed in 2007.

Peak flows never exceeded the 10-year target at Colin Creek South (02D) (Figure 41). Two-year target flows were exceeded during 2-year intensity storms or large multi-day events.

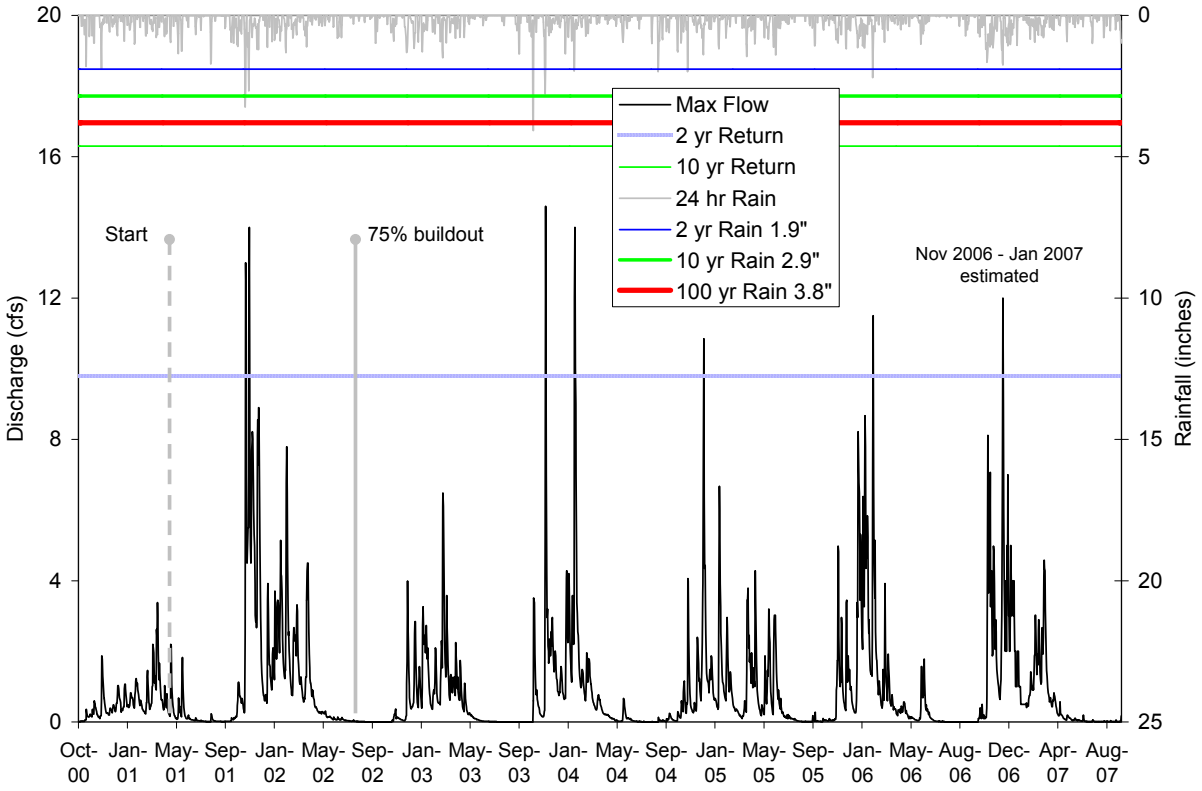

Figure 41. Maximum daily flow at the Colin Creek South (02D) gage.
Includes maximum daily rainfall totals. Construction began in 2001 and 75% buildout was reached in August 2002 in the Colin South basin.

Based on the flow duration plot from 2004-2006 (Figure 42) for flows less than 10 cfs, flow durations at gage 02D are matching the target predevelopment modeled durations. The 2008-2010 monitoring report will include an HSPF model run with the rainfall for the gaged period to verify this.

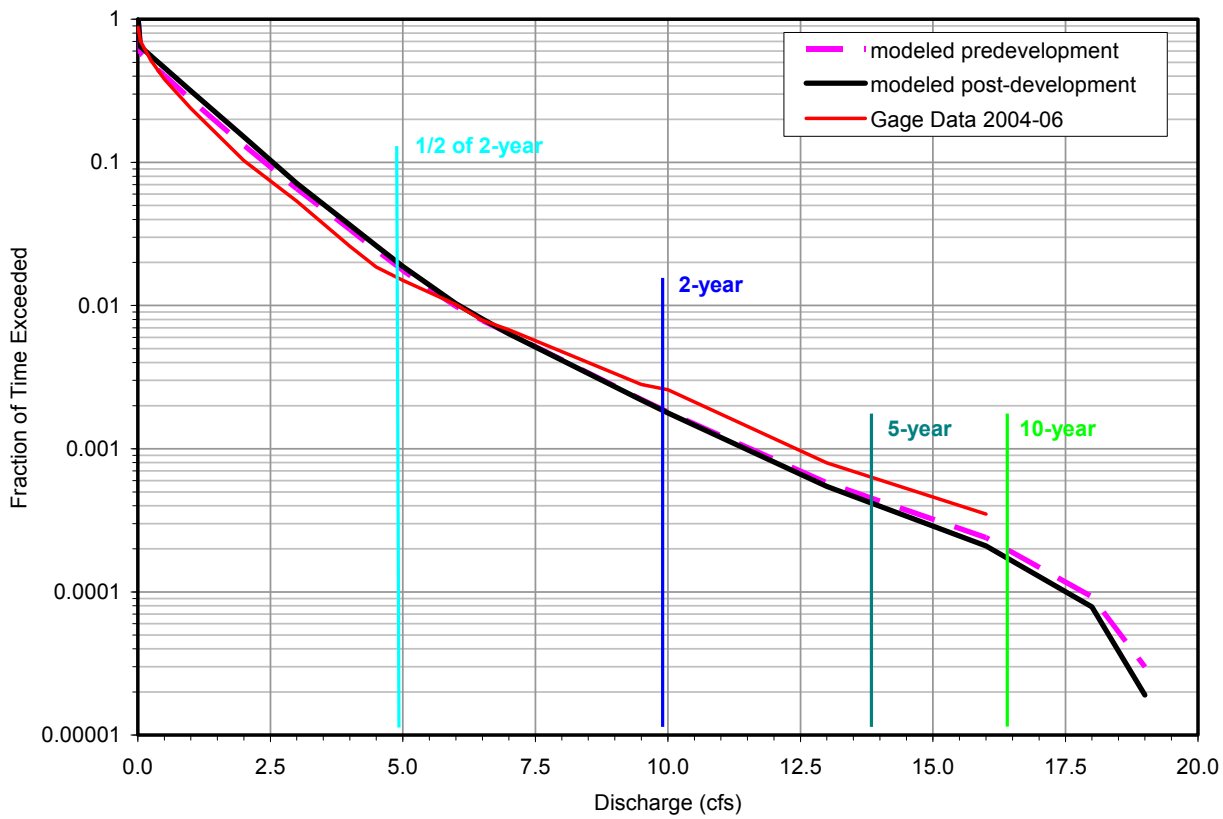

Figure 42. Flow duration curve for Colin Creek South (02D) for 2004-2006.

Colin Creek South frequently goes dry at the gage (02D) (Table 23).

Table 23. Number of days Colin Creek South goes dry.
Dates are based on the gage record (02D).

Year	Days Dry	Year	Days Dry
1990	85	2001	0
1991	110	2002	66
1992	70	2003	80
1993	30	2004	40
		2005	0
		2006	50
		2007	0

Redmond Ridge

Evans Creek West Drainage: Rutherford Creek (Gage 18F)

Post-development flow data collection began at Rutherford Creek (18F) in October 2000. The monitoring site is located behind a rectangular concrete weir, which was originally set up for the baseline monitoring. During the 2004 wet season the weir started to leak, and the flow monitoring location was moved upstream of the NE 76th Street road crossing. A stage-discharge rating curve was developed for the site using a weir equation and direct measurements of discharge.

Rutherford Creek is an offsite monitoring location and receives drainage from developed areas downstream of the UPD as well as from the UPD itself. In 2004 and 2005, there were a number of incidents of beaver dams being broken downstream of the UPD causing unusually high flows. The Redmond Ridge hydrologic analysis (Northwest Hydraulic Consultants Inc. 1994) established flood frequency targets for Rutherford Creek. Figure 43 displays the maximum daily flow for Rutherford Creek (18F) and shows the 2-, 10- and 100-year target peak flows. The 10-year target flow was exceeded in 2004 and 2005 and was approached in 2006 and 2007. Future monitoring of facilities draining from the Evans Creek West subbasin will provide additional information about the source of peak flows.

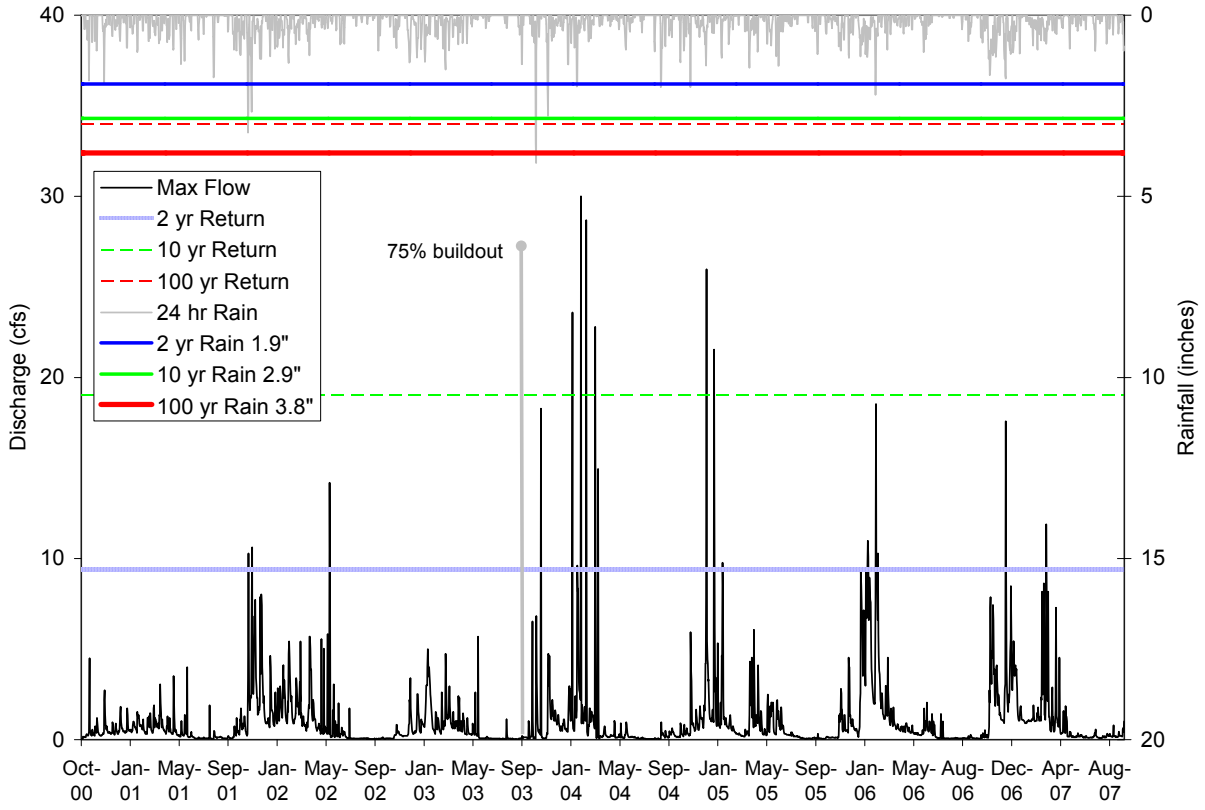

Figure 43. Maximum daily flow at the Rutherford Creek (18F) gage.
Includes maximum daily rainfall totals. Construction began in 1999 and 75% buildout was reached in October 2003 in the Rutherford basin.

The Redmond Ridge hydrologic analysis did not set flow duration targets for Rutherford Creek at the gage location; however estimations were made from modeling done for EC-3, the Rutherford Creek headwater wetland[53]. This analysis indicates that flow durations may be higher than the target for flows above one half the 2 year target peak flow (Figure 43). The modeled post-development duration curve (Figure 44) shows flows would exceed 6 cfs 1% of the time. The gage record for the three years exceeded 7 cfs 1% of the time, a 16% increase. The

[53] There is a chart of flow duration exceedance probability in the Northridge Master Drainage Plan for EC-3 (Northwest Hydraulic Consultants Inc. 1994). The modeled future and existing exceedance probabilities are plotted by estimating points from the figure in the NHC report and plotting them with the gaged duration probabilities from 2004 to 2006 (Figure 44).

0.1% exceedance was 10 cfs for the modeled post-development flows, and 13 for the gage record, a 30% increase.

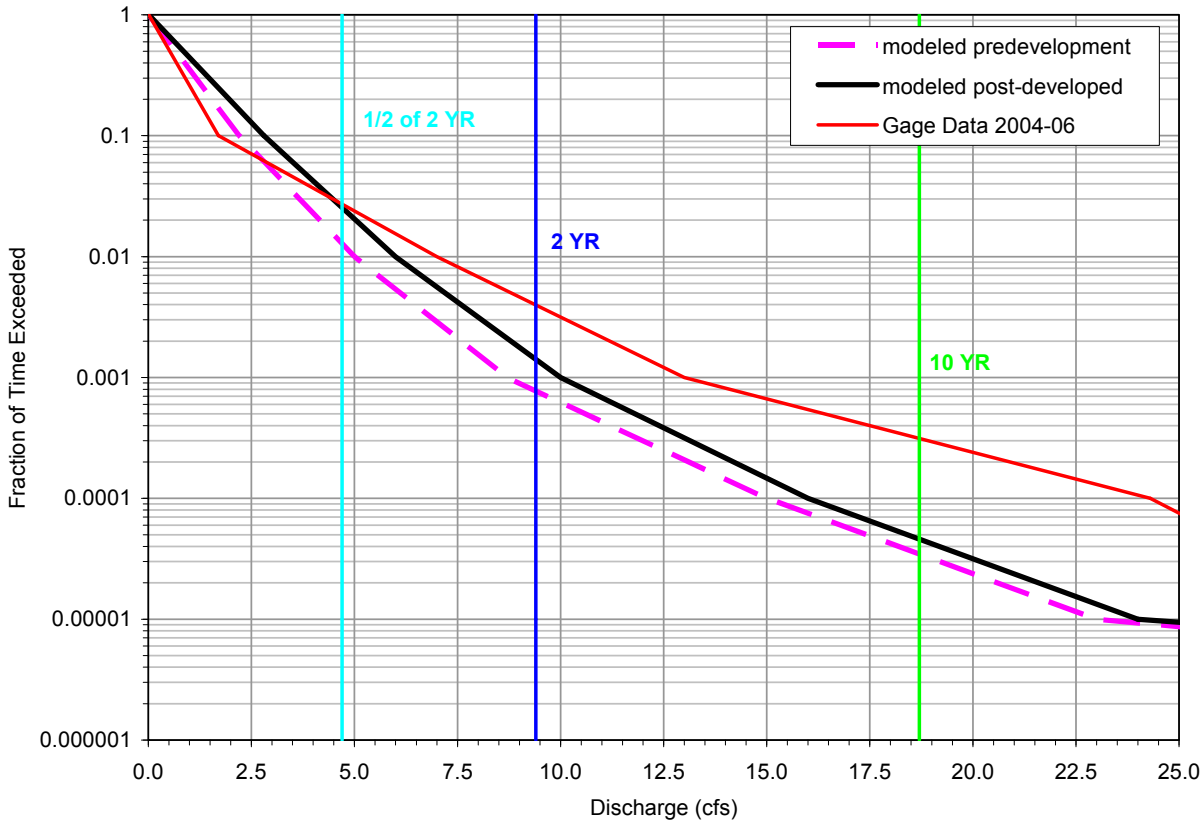

Figure 44. Flow duration curve for Rutherford Creek (18F) for 2004-2006.

The Rutherford Creek channel did not go dry during the monitoring period.

<u>Evans Creek Central Drainage: Evans Creek Central – South Weir (Gage 18B)</u>

Monitoring at gage 18B was started in October 1998 at the south weir, which is a 10-foot-long thin crest weir constructed for baseline monitoring in 1990. The gage measures the discharge from wetland EC-4. Equipment failure and WLRD staffing reductions caused loss of data during winter 2005 and 2007. A new level recorder will be installed in 2008.

Figure 46 shows flows for October 2000 through September 2007 at the south weir with the target post-development 2-year peak flow. The 2-year peak flow target was exceeded twice, both times during 2-year 24-hour rain storms.

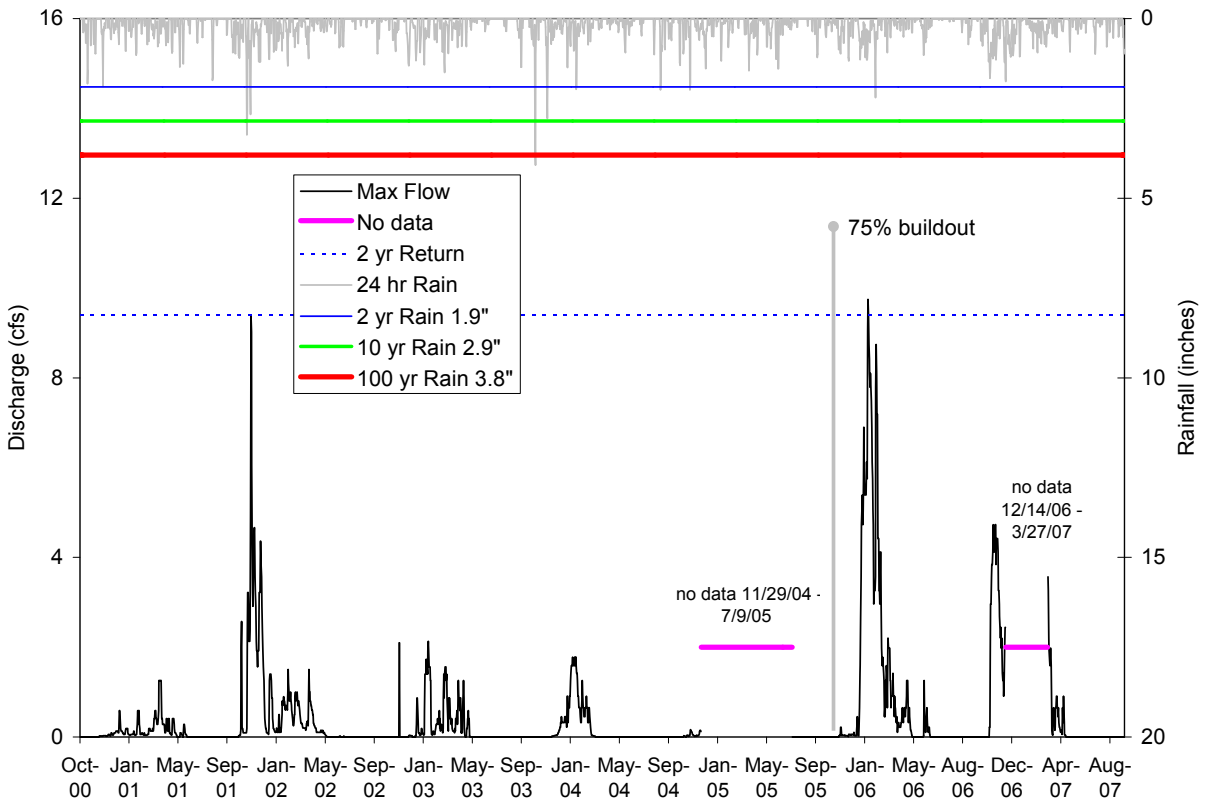

Figure 45. Maximum daily flow at the Evans Creek Central South Weir (18B) gage.
Includes maximum daily rainfall totals. Construction began in 2000 and 75% buildout was reached in October 2005 in the Evans Central basin.

A plot of flow duration probabilities for the EC-4 outlet is included in the Northridge Master Drainage Plan (Northwest Hydraulic Consultants Inc. 1994). However, a duration analysis of the gage record cannot be performed because of the gaps in the gage record.

The site goes dry every summer, but channel drying is no more persistent than in the predevelopment period (Table 24).

Table 24. Number of days Evans Creek Central South Weir goes dry.
Dates are based on the gage record (18B).

Year	Days Dry	Year	Days Dry
1989	170	2001	120
1990	no data	2002	175
1991	150	2003	200
1992	165	2004	220
1993	100	2005	150
		2006	140
		2007	150

Threshold Exceedance Criteria and Evaluation

Comparisons to the threshold criteria are made in the discussion of results for each stream gaging location (see previous section) and are summarized here. Initial analyses suggest that modeled flow duration targets are exceeded at three streams [Colin North (02C), Adair (53A), and Rutherford (18F) Creeks]; peak flow targets are exceeded at Rutherford Creek (18F); and summer channel drying duration may have changed at Adair Creek (53A) (Table 25).

Table 25. Summary of stream hydrology threshold exceedances and recommendations.

Site Code	Name	Criteria Exceedances	Recommended Action
		Trilogy	
02C	Colin Creek North	Flow durations	Run HSPF model
02D	Colin Creek South	No exceedances	Run HSPF model
53A	Adair Creek	Flow durations, channel drying	Run HSPF model
53B	Wallace Creek West	No exceedances	Run HSPF model
53C	Wallace Creek North	No exceedances	Continue monitoring
53D	Adair Creek Bypass	Captures summer baseflow	Investigate flow splitters
53F	Wallace Creek Bypass	No exceedances	Continue monitoring
		Redmond Ridge	
18F	Rutherford Creek	Peak flows, flow durations	Run HSPF model, analyze flows from ECW facilities[54]
18B	Redmond Ridge ECC South Weir	No exceedances	Run HSPF model

Corrective Actions

No corrective actions are recommended pending the results of additional investigations and analysis summarized in Table 25. The 2008-2010 monitoring report will include more analysis of the performance of stormwater facilities that affect the streamflows, and HSPF modeling runs that will produce more accurate comparisons to the threshold criteria.

3.8 Stream Channel Characterization (Longitudinal Surveys)

Stream channel characterizations (i.e., longitudinal stream surveys) were included in both the Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) in order to try to capture potential changes to fish habitat and downstream channel characteristics resulting from UPD development. Channel characterization stream walks were called for in 9 creeks (Adair, Wallace, Colin North, Colin South, Colin East, Evans East, Evans Central, Mackey, and Rutherford Creeks) (Figure 4). Characterizations were scheduled to begin the first year of

[54] Flow monitoring will be initiated at ECW3-1 (2008 water year) and ECW2-1 (2010 water year) and data from these facilities may help in the interpretation of Rutherford Creek flow data.

construction within a subbasin and continue annually for a maximum of 12 years (King County 1999) or until 3 years after 75 percent buildout in each subbasin; alternatively, they could be spaced at 1, 3, 5, and 10 years following construction startup (King County 2001).

Surveys were conducted in 1998, 1999, 2000, 2001, and 2002[55]. Evans Central and Colin South Creeks were surveyed in 2005, after which channel characterization surveys were discontinued because of the difficulty in obtaining landowner permission for the entire length of each reach, the inherent variability of the protocols used, and the inability of the chosen methodologies to link changes to upstream development as opposed to changes in field personnel. For these reasons, this monitoring parameter will be discontinued in all future years.

3.9 Stream Channel Stability (Stream Cross-Sections)

Increases in peak flow and duration, which often result from increases in impervious area related to urbanization, can increase sediment transport and destabilize stream channels (Booth 1990). UPD planning involved extensive stormwater modeling and 55 stormwater ponds (27 Redmond Ridge, 28 Trilogy) have been constructed to minimize such impacts. Regular measurements of stream cross-section dimensions at 2 to 5 locations in 7 streams facilitate tracking changes in channel shape over time. Five Adair Creek cross-sections were measured in 2007 (Figure 46). See Appendix M for details of the monitoring schedule through 2007.

[55] See University of Washington Reports (Comings et al. 2000, Comings et al. 2001a, b) for 1998-2001 data summaries. 2002 and 2005 data were not previously reported, but are displayed in Appendix L.

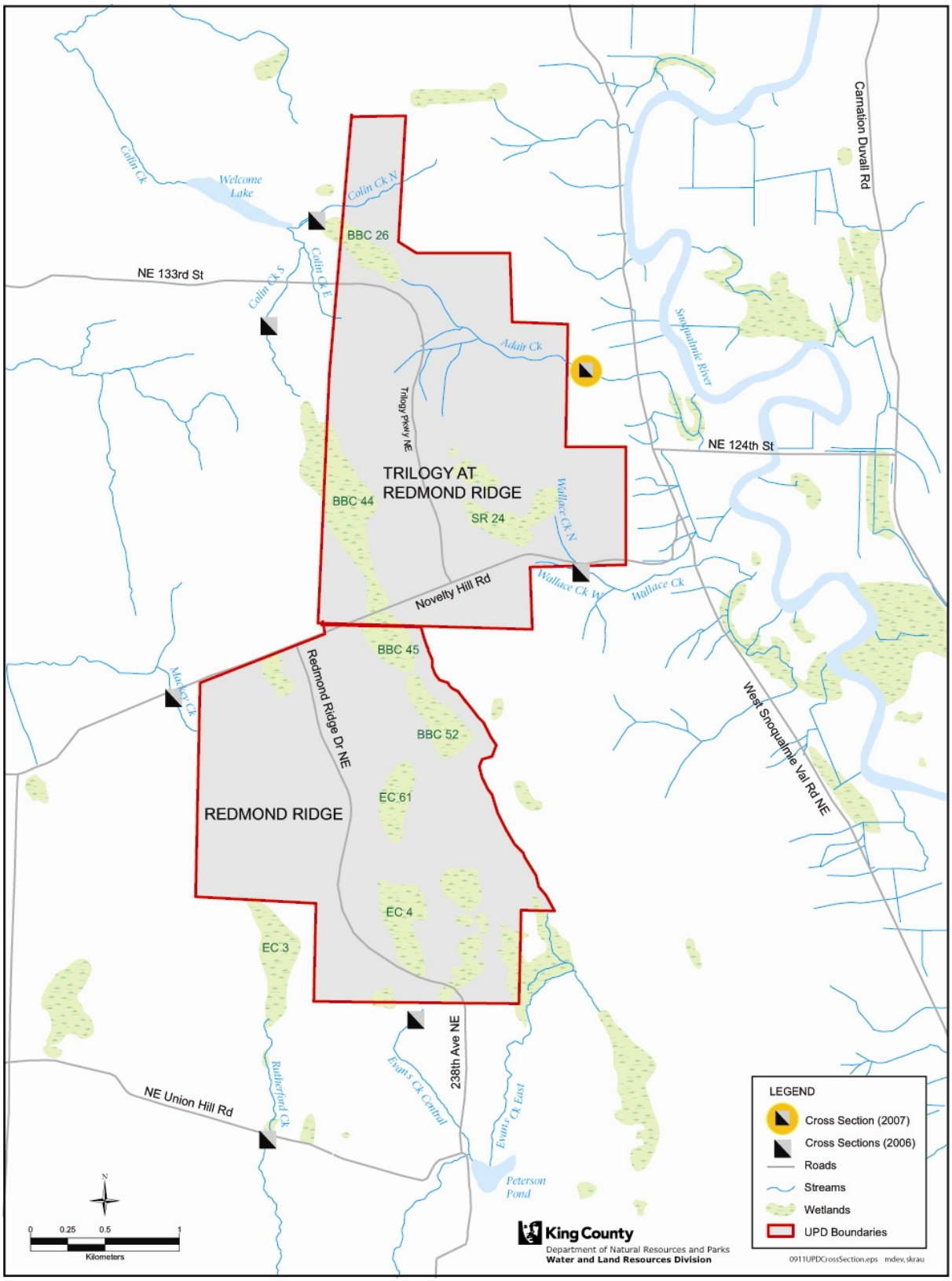

Figure 46. Approximate location of stream cross-section measurements.
Cross-section dimensions were measured in 2007 at Adair Creek. Five established cross-sections are spaced over a 50 m reach within the vicinity of the symbol shown.

Modifications

Annual stream channel stability monitoring was required on seven streams (Adair, Colin North, Colin South, Wallace, Rutherford, Evans Central, and Mackey Creeks[56]) draining the UPDs beginning in the first year of subbasin construction and continuing for a maximum of 12 years at Redmond Ridge (King County 1999) or for 3 years after 75 percent buildout at Trilogy (King County 2001). Alternatively, the Trilogy monitoring plan (King County 2001) allows for spacing the sampling through time at 1, 3, 5, and 10 year intervals following construction start-up including one time after full buildout (King County 2001). Monitoring was conducted at the seven streams almost annually[57] between 1998 and 2002 then again in 2005 and 2006. Beginning in 2007, monitoring was limited to only two streams (Wallace and Adair Creeks) spaced on an every other year schedule (see "Sampling Recommendations" below).

Sampling Recommendations – Data presented in the Midpoint Report (King County 2006) suggest that the streams that were selected for monitoring have not changed in relation to the predevelopment conditions. In addition, the majority of these monitoring locations are immediately downstream of large headwater wetlands in very low gradient systems where changes in channel shape are not likely. Therefore, except for a final site visit at least 7 years after construction start-up at each site, future monitoring should be limited to Wallace and Adair Creeks, which are higher gradient systems where both natural and landuse-induced changes are more likely. Sampling at Wallace and Adair will take place approximately every other year. In addition, field data collection methods will revert to those used from 1991-2005 rather than those used in 2006-2007.

Procedures

In 2006 and 2007, bed surface elevations at each cross-section were measured using an autolevel and stadia rod following standard survey protocols (Harrelson et al. 1994). The horizontal locations relative to the marked end points for each measurement are calculated using basic trigonometry equations. Field data collection methods from 1991-2005 used a tape measure stretched between the two end points to determine the horizontal position, and an autolevel and stadia rod to determine the bed surface elevation at each measurement point[58]. In both cases, bed surface elevation was recorded at locations determined using best professional judgment to capture any significant geomorphic features (e.g., bankfull, thalweg, edge of water) or any inflection points (typically 15 to 30 measurements per cross-section). The left bank end point is set at a relative elevation standardized across years and each cross-section is compared to all previous years to see if the stream channel cross-section has changed through time.

Results

Results from the stream channel stability cross-section surveys at Adair Creek are presented in Figures 47-51. As mentioned above in the 'procedures' section, there were field data collection changes beginning in 2006. Theoretically both methods should yield comparable results. However, changes in cross-section profiles coincide with these methodological changes. Cross-

[56] Evans Creek East was monitored in 2002; however this stream was never mandated and has not been revisited.
[57] In 2001, only Adair Creek, Colin North, and Rutherford Creek were monitored.
[58] Trigonometry calculations were not required using the tape measure method for data collected between 1991 and 2005.

section data collected between 1991 and 2005 (Figures 47-51) generally reveal only minor year-to-year fluctuations in the cross-section profiles indicating that the channels were in a fairly stable state. However, the 2006 and 2007 profiles suggest changes in channel shape (for example, 2006 is wider and deeper and 2007 is wider than all other years (Figure 47) and 2006 profiles are statistically different from all other years at cross-sections 1, 3, and 4.

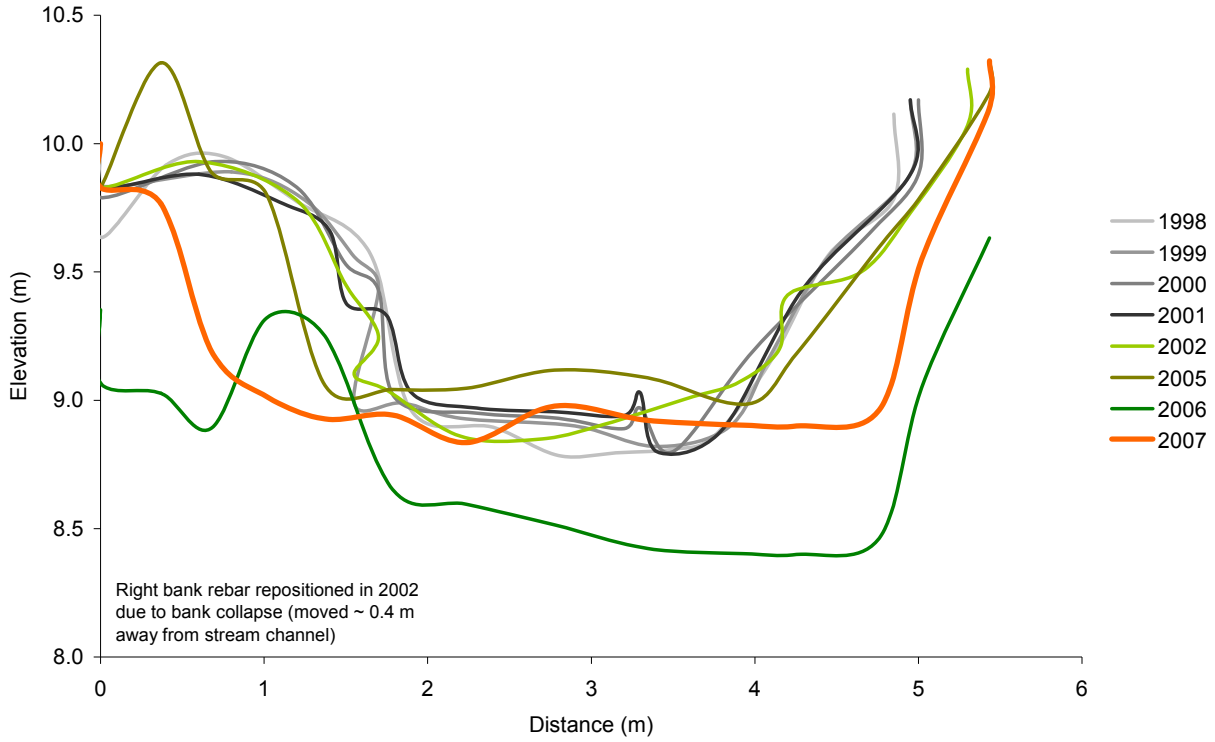

Figure 47. Stream channel survey results for Adair Creek lateral cross-section #1.
2006 and 2007 methods differed from earlier methods. Gray colors (1998-2001) represent predevelopment; greens (2002-2006) construction; orange (2007) post 75% buildout.

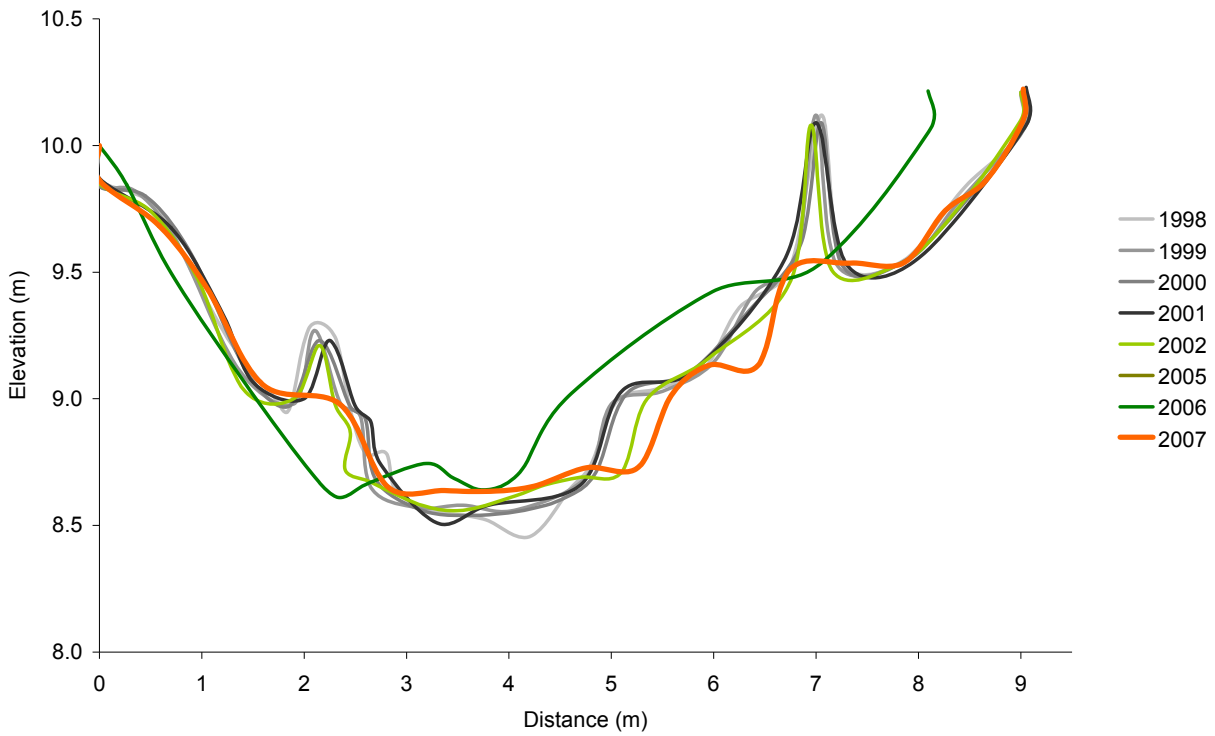

Figure 48. Stream channel survey results for Adair Creek lateral cross-section #2.
2006 and 2007 methods differed from earlier methods. Gray colors (1998-2001) represent predevelopment; greens (2002-2006) construction; orange (2007) post 75% buildout.

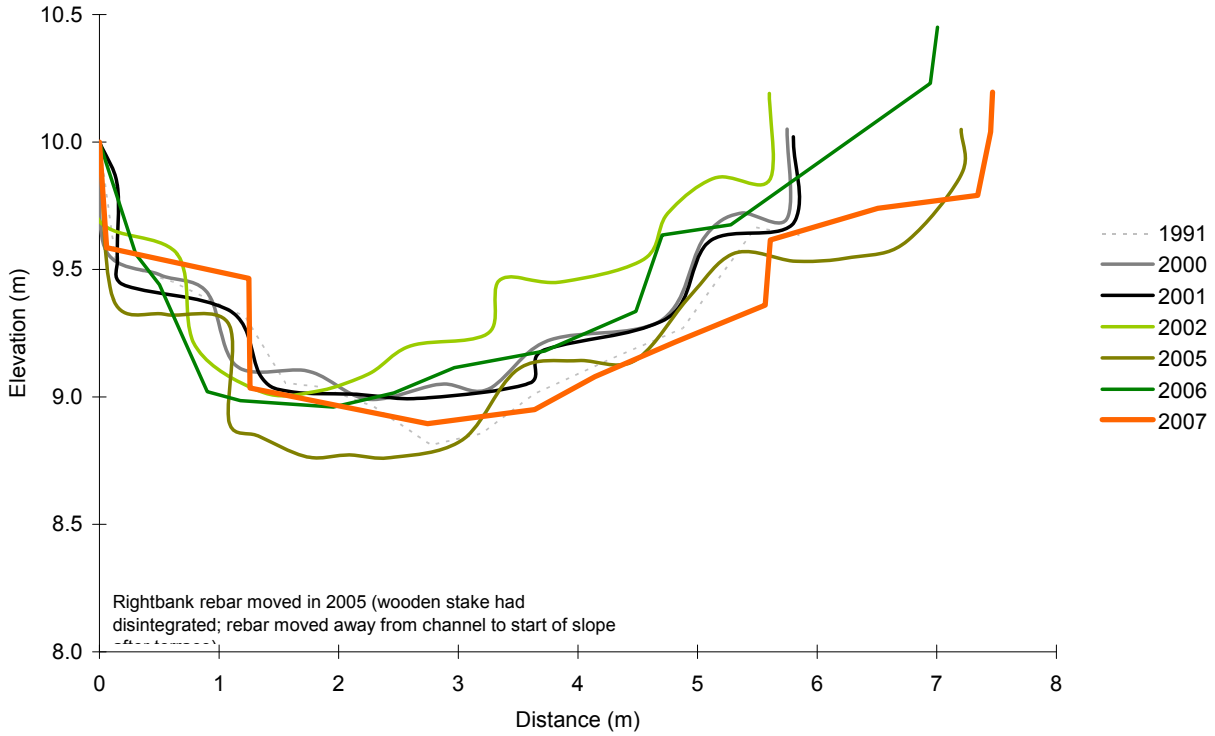

Figure 49. Stream channel survey results for Adair Creek lateral cross-section #2b.
2006 and 2007 methods differed from earlier methods. Gray colors (1998-2001) represent predevelopment; greens (2002-2006) construction; orange (2007) post 75% buildout.

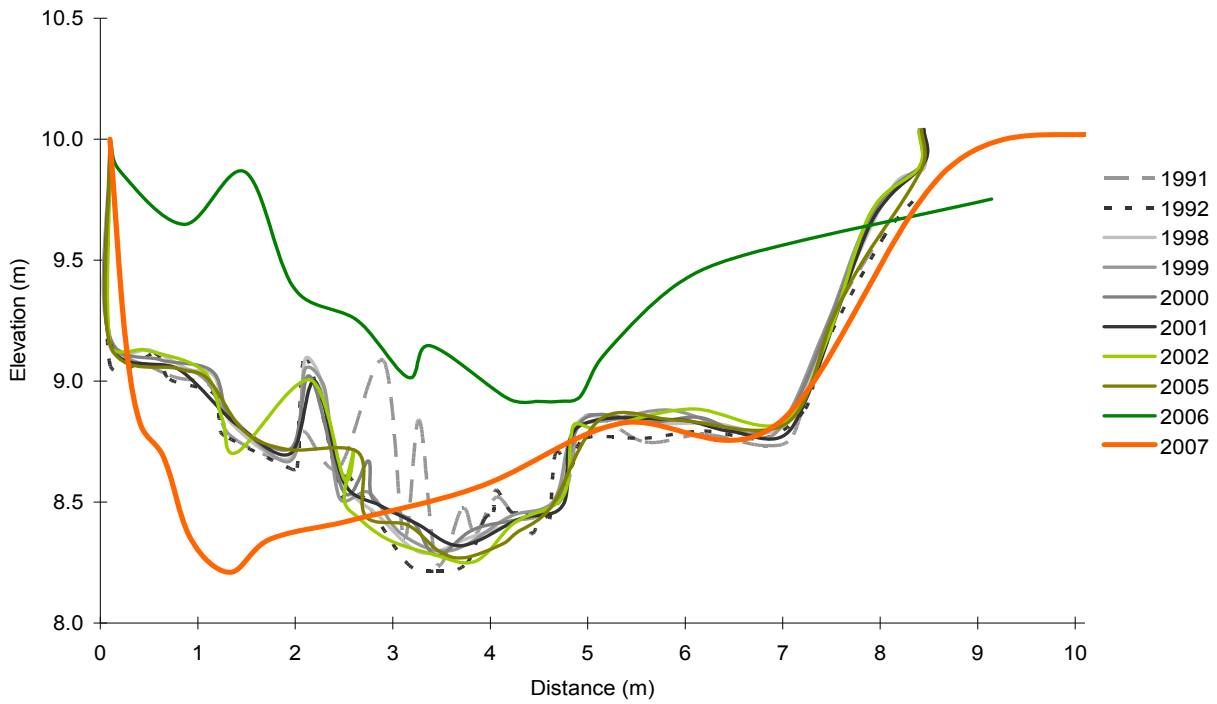

Figure 50. Stream channel survey results for Adair Creek lateral cross-section #3.
2006 and 2007 methods differed from earlier methods. Gray colors (1998-2001) represent predevelopment; greens (2002-2006) construction; orange (2007) post 75% buildout.

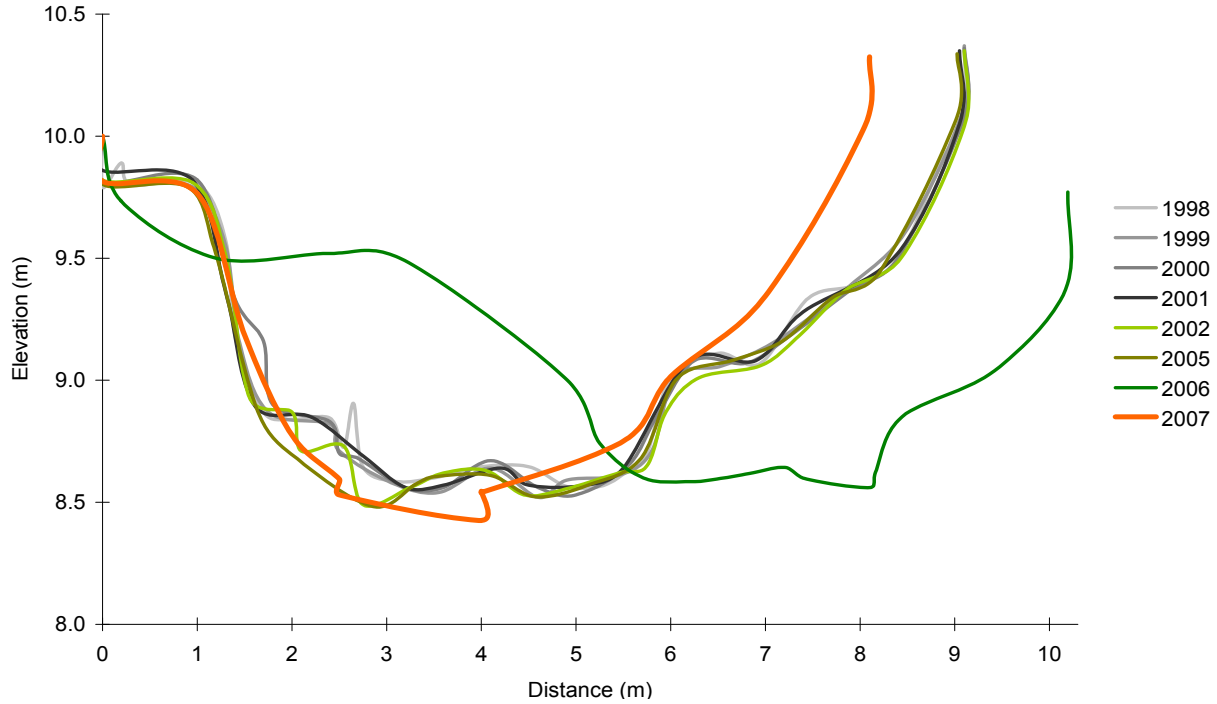

Figure 51. Stream channel survey results for Adair Creek lateral cross-section #4.
2006 and 2007 methods differed from earlier methods. Gray colors (1998-2001) represent predevelopment; greens (2002-2006) construction; orange (2007) post 75% buildout.

Threshold Exceedance Criteria and Evaluation

Any changes from predevelopment conditions exceeding the bank erosion and bed erosion or deposition criteria shown in Table 26 violate the thresholds established in the Trilogy and Redmond Ridge monitoring plans and could trigger appropriate corrective actions (King County 1999, 2001). From a qualitative perspective, Adair Creek seems to be functioning as expected with no major depositional or erosional areas that aren't explained by natural fluctuations or large logs falling across the channel (the curved 'blips' in the cross-section graphs are usually logs, which were not measured in all years). 2006 and 2007 cross-sections appear to violate the threshold exceedance criteria; however, these changes are assumed to be attributed to changes in field data collection methods rather than direct impacts from upstream UPD development. Future data collection will confirm or refute this assumption.

Table 26. Threshold exceedance criteria for stream cross-section locations.
Erosion or deposition exceeding the values in this table violate these thresholds and may trigger corrective actions (King County 1999, 2001).

UPD	Lateral bank erosion	Bed erosion/ deposition @ any point	Bed erosion/deposition averaged
Redmond Ridge	5.9 in (15 cm)	3.1 in (8 cm)	1.2 in (3 cm)
Trilogy	13 in (34 cm)	5 in (13 cm)	5 in (13 cm)

Corrective Actions

No corrective actions are recommended for this component of the monitoring plans. Resuming 1991-2005 field data collection methods should allow more direct comparisons of pre- and post-development conditions.

3.10 Water Quality

Good water quality is essential for proper functioning of aquatic ecosystems and survival of sensitive aquatic organisms. Yet anthropogenic changes in a watershed, such as increased development and urbanization, often alter water quality through increased delivery or concentration of nutrients, pesticides, organic chemicals, and heavy metals found in urban runoff and treated wastewater (Klein 1979, Heaney and Huber 1984, May et al. 1997, Brown et al. 2005). The monitored wetlands within the Trilogy and Redmond Ridge UPDs have low pH, total alkalinity (acid neutralizing capacity), and hardness typically found in bogs and bog-like wetlands[59]. Therefore, the urbanization of surface water flows, which are generally nutrient and cation enriched, poses a concern for maintaining the integrity of these bog and bog-like wetlands and their receiving waters (Kulzer et al. 2001).

Water quality sampling is conducted annually three times between January and April at 20 locations (Figure 52), including a subset of predevelopment baseline locations. See Appendix N for details of the Water Quality sampling schedule through 2007.

[59] The Seattle District of the Army Corps of Engineers defines "bogs and bog-like wetlands" as wetlands with "hydric soils (peat and/or muck) typically 16 inches or more in depth…; vegetation such as spruce, western hemlock, lodgepole pine, cedar, white pine, crabapple, or aspen; and may be associated with open water" (Army Corps of Engineers 2007). All monitored UPD wetlands possess these characteristics.

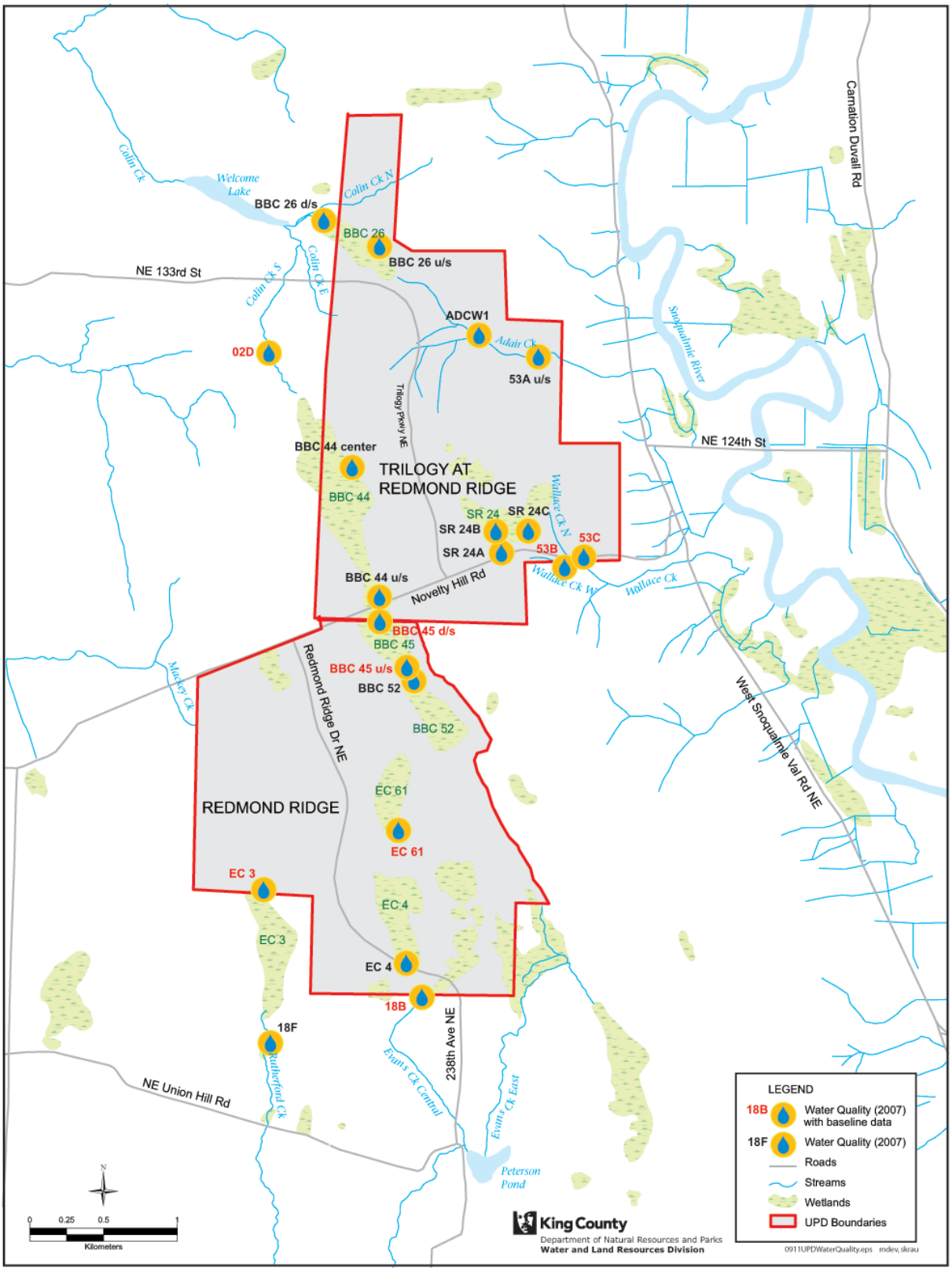

Figure 52. Location of 20 water quality sampling stations.
Includes 7 streams and 13 wetlands.

Modifications

The Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) detail four different sampling outlines related to stream and wetland water quality. Modifications to the original plans appear in italics below:

1. Trilogy wetlands: Three visits annually between January and March to 11 wetland sites (including 8 baseline sites) to sample *in situ* pH, temperature, and specific conductivity beginning in 2002 and continuing until 3 years following 75 percent subbasin buildout. In addition, alkalinity and hardness laboratory parameters are added when 75 percent subbasin buildout is reached. *This monitoring component has been expanded to cover 20 sites total (Figure 52) including 7 streams and 13 wetlands across both the Trilogy and Redmond Ridge UPDs. The three annual samples are collected between January and late April[60] (as opposed to March). Alkalinity and hardness were added in 2006, which was after 75 percent buildout in some of the subbasins. Though not required, total metals data are available in conjunction with the hardness values, and dissolved oxygen and turbidity data have been collected. This sampling component will be referred to as 'January through April sampling' throughout the remainder of this report.*

2. Trilogy streams: Continuous temperature and turbidity monitoring at Adair, Wallace, Colin North, and Colin South gage locations in addition to summer, winter, and spring pH measurements beginning at 75% subbasin buildout for three years. *Wallace Creek North was monitored for continuous temperature from 2002 to 2004, but because this creek goes dry in the summer when high temperatures are most likely, the temperature monitoring was discontinued. Turbidity monitoring was abandoned for all streams in 2005 because of equipment fouling. See Appendix 4.3.1 in the 2006 Midpoint Report for details (King County 2006). Monitoring of pH has continued, although the acidic conditions combined with low hardness and conductivity have made achieving reliable measurements difficult. Summer pH measurements are not collected.*

3. Redmond Ridge streams: Continuous temperature and turbidity monitoring at Colin Creek South and Rutherford Creek gage locations in addition to monthly pH measurements beginning the first year of construction and continuing until three years following 75 percent subbasin buildout. *Colin Creek South was also required under the Trilogy stream monitoring because it originates from a chain of wetlands that extends across both UPDs (see #2 above). Evans Creek Central, though not required, was monitored from 2000 to 2001. Monitoring of pH has continued, although the acidic conditions combined with low hardness and conductivity have made achieving reliable measurements difficult. January, February, and April pH measurements are performed, though other required monthly pH measurements have never been done.*

4. Redmond Ridge wetlands: Twice annual monitoring of conductivity, dissolved oxygen, temperature, turbidity, organophosphorus pesticides, chlorinated herbicides, total phosphorus, total nitrogen, and nitrate+nitrite (NO_2+NO_3) during (1) summer low flow and (2) an early fall storm that is likely to flush accumulated summer pollutants

[60] There has been one sample date in May: May 1, 2007.

beginning in 2000 and continuing until four years following 75 percent subbasin buildout at BBC-52 and BBC-45 d/s. *Initiation of this monitoring component is delayed.*

Sampling Recommendations – Continue with January through April sampling and continuous stream temperature sampling. January through April sampling within the Rutherford and Colin South subbasins will be discontinued because the required monitoring duration has been met and exceeded[61]. Initiate Redmond Ridge wetland water quality monitoring in future years at BBC-52 and BBC-45d/s.

Procedures

Two distinct water quality monitoring programs have been conducted on the UPDs through 2007: (1) January through April sampling and (2) continuous sampling. The procedures for these two programs are discussed below.

January through April Sampling

Twenty locations, including 7 streams primarily downstream of the UPDs and 13 onsite wetlands, are sampled annually in January, February, and April (Figure 52) for water quality. Conventional parameters including turbidity, temperature, dissolved oxygen, conductivity, and pH are measured *in situ*, and beginning in 2006 water samples also are collected and analyzed for alkalinity, hardness, and total metals concentrations.

At each sampling location, turbidity is measured using a Hach 2100P Turbidimeter before any other samples or measurements are taken to minimize disturbance that could impact measurements. Turbidity is always compared to three standard solutions at the beginning and end of each sample day (Hach 1999).

Temperature, dissolved oxygen, and conductivity measures are collected using either an YSI model 85[62] handheld system or a Hydrolab water quality sonde. Each field probe is calibrated for the parameters at the beginning of each day and checked for drift against known standards at the completion of daily sampling.

Measurement of pH is expressed as the negative logarithm of the hydrogen ion concentration. EM-Reagents color pHast® paper 4.0-7.0 range are primarily used to measure pH, although pH 2.5-4.5 or 6.5-10 paper have been used when conditions warrant it. Periodically, pH is also measured using a variety of meters (e.g., Oakton pHTestr2, Orion model 230Aplus portable pH meter, or the Hydrolab water quality sonde). Reliably measuring pH has been challenging in the low hardness and low conductivity UPD surface waters: finding that the various probes and pH paper types produce differing results despite correctly recording QA/QC checks of standard solutions. The problem is likely related to the softness of the water, unlike the standards which are very high in dissolved ions and are consequently more stable. Hydrolab measurements are presumed to be more accurate and less subjective than the pH paper, which seems to consistently

[61] January through April sampling was mandated for three years after 75% buildout. Water quality sampling in Rutherford and Colin South Creeks continued for four and five years after 75% buildout, therefore exceeding the required monitoring duration (Appendix N).

[62] In lentic environments, the YSI probe was gently bobbed through the water column below the surface because the dissolved oxygen probe is stirring dependant (YSI Incorporated 1998)

underestimate pH. In order to compare data over time, the results from 2002-2006 using pH paper have been multiplied by a factor of 1.242, derived from a linear regression of data collected by both methods over a period of time ($r^2 = 0.529$). From 2007 onward, pH will be measured using a Hydrolab[63].

Beginning in 2006, water samples are collected in pre-labeled containers for hardness, alkalinity, and total metals concentrations[64]. Two bottles are collected at each site and stored on ice until delivery to the EPA-approved King County Environmental Lab (KCEL). Each parameter is analyzed by KCEL using standard operating procedures (King County Environmental Lab 1999, 2003, 2006) and following strict protocols for sample handling and quality assurance.

Analysis is confined to visually evaluating graphs of data over time because the quantity of predevelopment data is not sufficient to establish the range of natural variability and to do rigorous statistical comparisons.

Continuous Sampling

In addition to the *in situ* sampling described above, continuous temperature gages record stream temperature every 15 minutes at the hydrology monitoring stations of five streams draining the UPDs: Adair, Evans Central, Wallace West, Colin South, and Colin North Creeks[65]. These gages are visited approximately every 6-8 weeks for data uploading and battery checks, the data are checked as part of a quality assurance and quality control (QA/QC) program and the results are posted on the King County Hydrologic Information Center website (link[66]).

Continuous turbidity sensors were also installed to shine light into the stream water and detect the amount of light scattered. The result is stored by the gage data logger.

Results

The low turbidity values and low nutrient levels from predevelopment water quality results (1981-84 and 1990-92) were comparable to other Puget Sound area surface waters dominated by relatively undisturbed wetlands (Herrera Environmental Consultants Inc. 1992, King County 1993, Comings et al. 2000). However, lead, copper, and zinc concentrations exceeded state standards at several of the predevelopment monitoring locations (Beak Consultants Incorporated 1995). See Appendix D of the 1998-99 University of Washington Monitoring Report for a complete reporting of the predevelopment water quality data (Comings et al. 2000); Appendix 4.3.1.3 of the Midpoint Report for 2002-2006 data (King County 2006); and Appendix Q in this report for *in situ* water quality data for each 2007 sampling date.

January through April Sampling

Where possible in the following sections, water quality results from January through April are compared with predevelopment January through April data collected in the same locations.

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[63] In contrast, the Midpoint Report (King County 2006) reported the pH paper results.
[64] Total metals concentrations are not mandated by the monitoring plans (King County 1999, 2001), but data are available as part of the laboratory analysis for hardness.
[65] The continuous temperature recording devices were removed at Evans Central and Wallace North Creeks in 2004. See the modifications section for justification and see Appendix O for the 2002 to 2004 data from these two creeks.
[66] http://green.kingcounty.gov/wlr/waterres/hydrology/

Results also are compared with state water quality standards, where appropriate. Figures are organized to show wetlands and streams from within the same subbasin on each graph. The streams generally drain from headwater wetlands or wetland complexes. See Figure 52 for the location and names of the water quality sampling sites, Figure 2 for the location of the subbasins, and Table 1 for a description of the subbasin abbreviations.

Specific Conductivity

Conductivity is a measure of the total dissolved constituents, including nutrients and pollutants, within the water. Although there are no established state or federal standards for conductivity, it is frequently used as an indicator of water quality because elevated values are associated with urbanization within a basin (Azous 1991, Horner et al. 2001a). Clinton and Vose (2006) found that conductivity was three to four times higher at urban headwater stream locations than at reference locations. Throughout this report when referencing conductivity, specific conductivity will be reported, which is standardized to a temperature of 25ºC.

Conductivity within both the BBC and ECC subbasins has remained steady across the years (1991, 2002-2007), despite some year-to-year fluctuations in the ECC subbasin[67] (Figure 53). In contrast, all other subbasins appear to exhibit some degree of increase in conductivity relative to predevelopment conditions. The NWD (Colin North) and ECW (Rutherford) subbasins show the strongest increases. The conductivity in BBC-26 wetlands (NWD subbasin) increased from less than 55 µS/cm between 2002 and 2004 to greater than 75 in 2007. Conductivity at the EC-3 wetland (ECW subbasin) was less than 60 µS/cm prior to 2004, but it was greater than 80 µS/cm from 2005 to 2007. However, even these increased wetland conductivity values are within the range of values found from wetlands in nonurban watersheds throughout the region in the 1980s and 1990s (Horner et al. 2001a)[68].

[67] Where conductivity was recorded using both a hydrolab and an YSI sonde, the average of the two measurements is reported.

[68] Conductivity of 190 wetlands in nonurban watersheds averaged 72.5 µS/cm with a median of 46.0 µS/cm (Horner et al. 2001a)

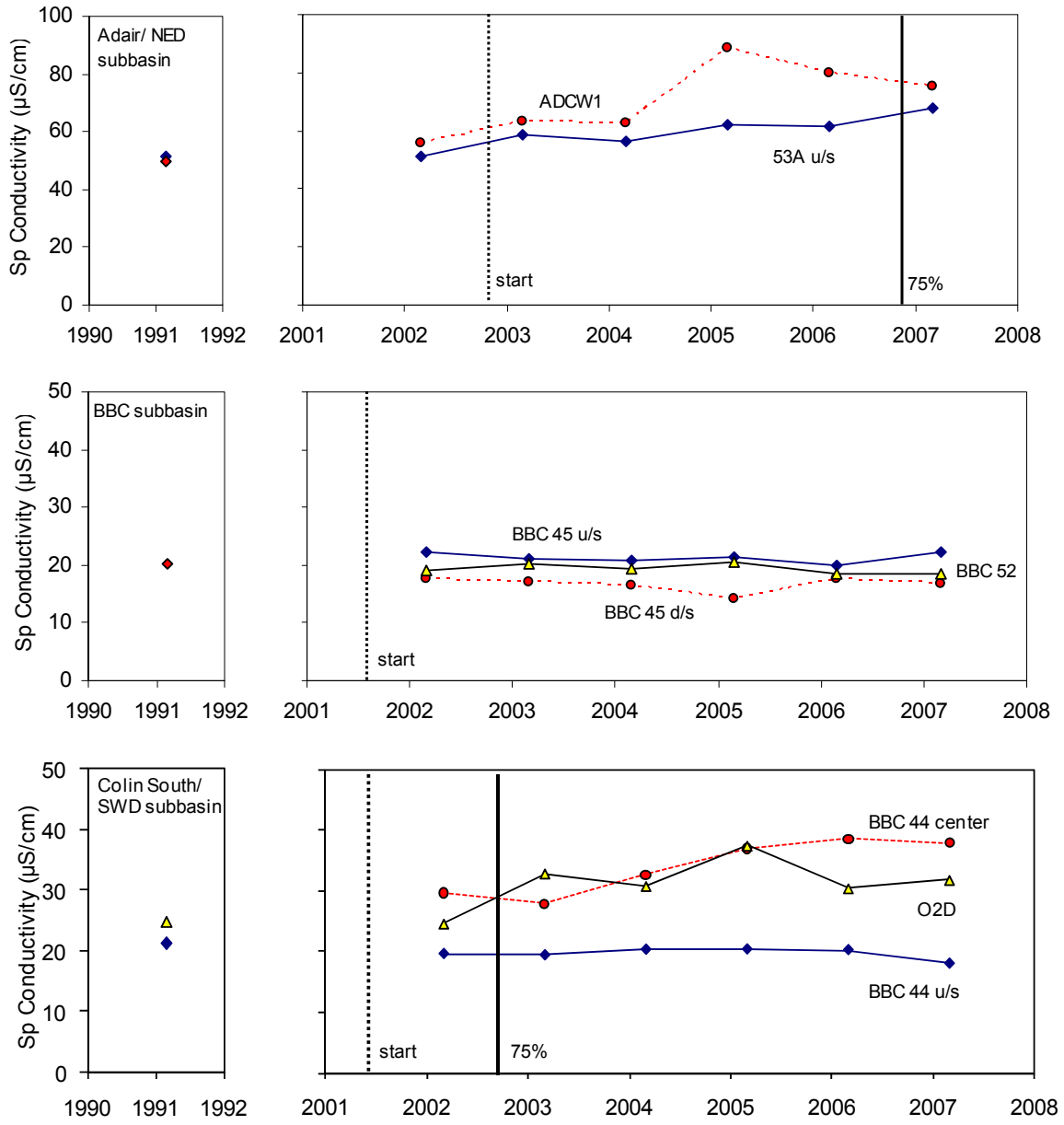

Figure 53. Average annual specific conductivity (1991, 2002-2007).
Data are averages of one to five measurements between January and April each year. Each graph represents a subbasin. The vertical dashed line labeled 'start' refers to the year construction and clearing began within the subbasin and the vertical solid line labeled '75%' represents the date when 75% buildout was reached within the subbasin. See Figure 52 for locations. (Cont'd next page)

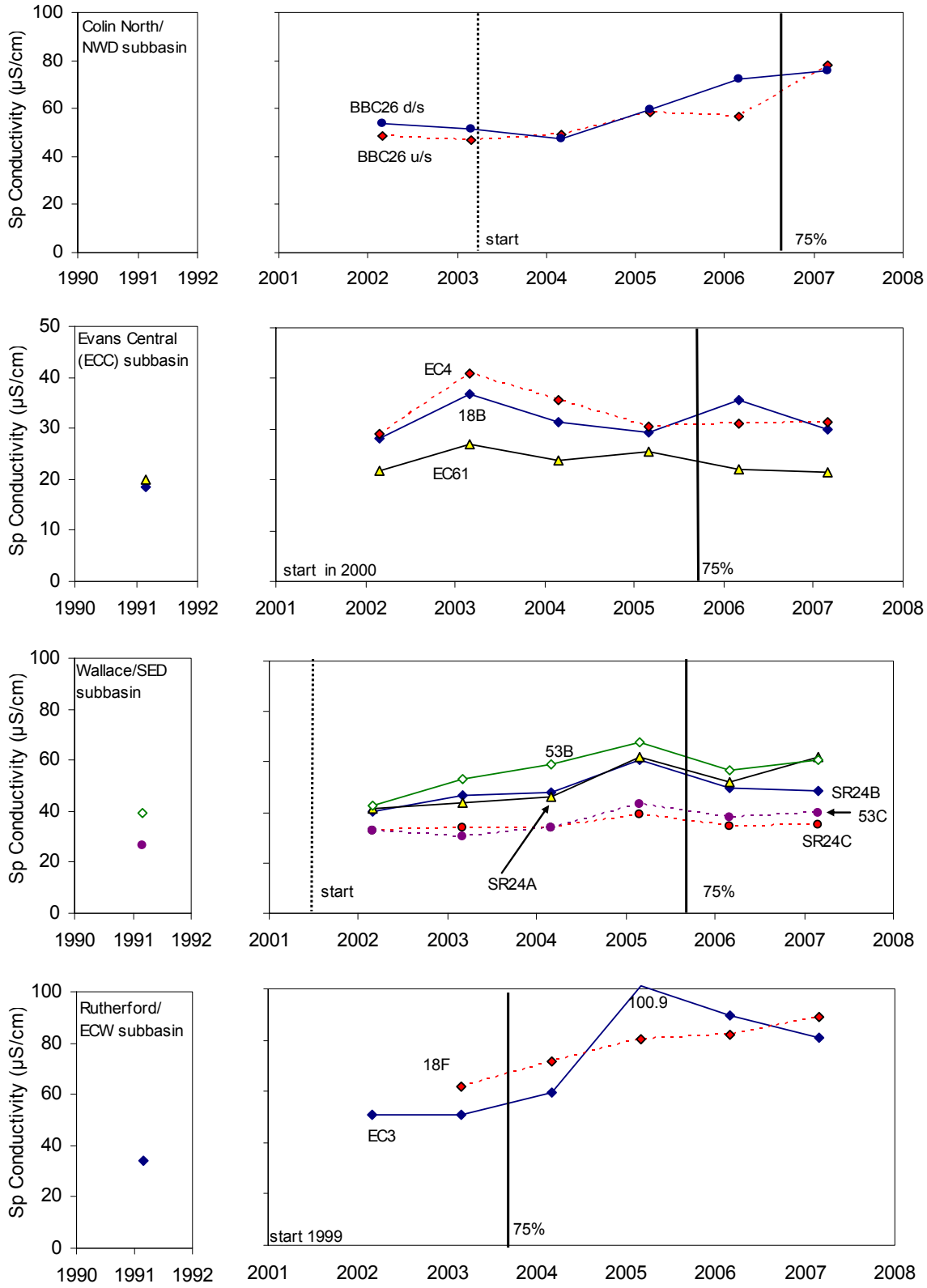

Figure 53. (Cont'd) Average annual specific conductivity.

Temperature

Adverse temperature impacts were not anticipated for UPD streams or wetlands[69] (Beak Consultants Incorporated 1995). Temperatures for all streams and wetlands showed relatively little change across years, hovering around an average of between 6 and 9ºC at each sampling site except BBC-26 u/s, which had an average of 10.3ºC across all years[70] (Figure 54). These temperatures are well below state standards of 17.5°C (63.5°F) for salmonid rearing and migration streams[71] (Washington Department of Ecology 2006). Temperatures were also recorded continuously at several stream gages (see 'Continuous Temperature Sampling' subsection below).

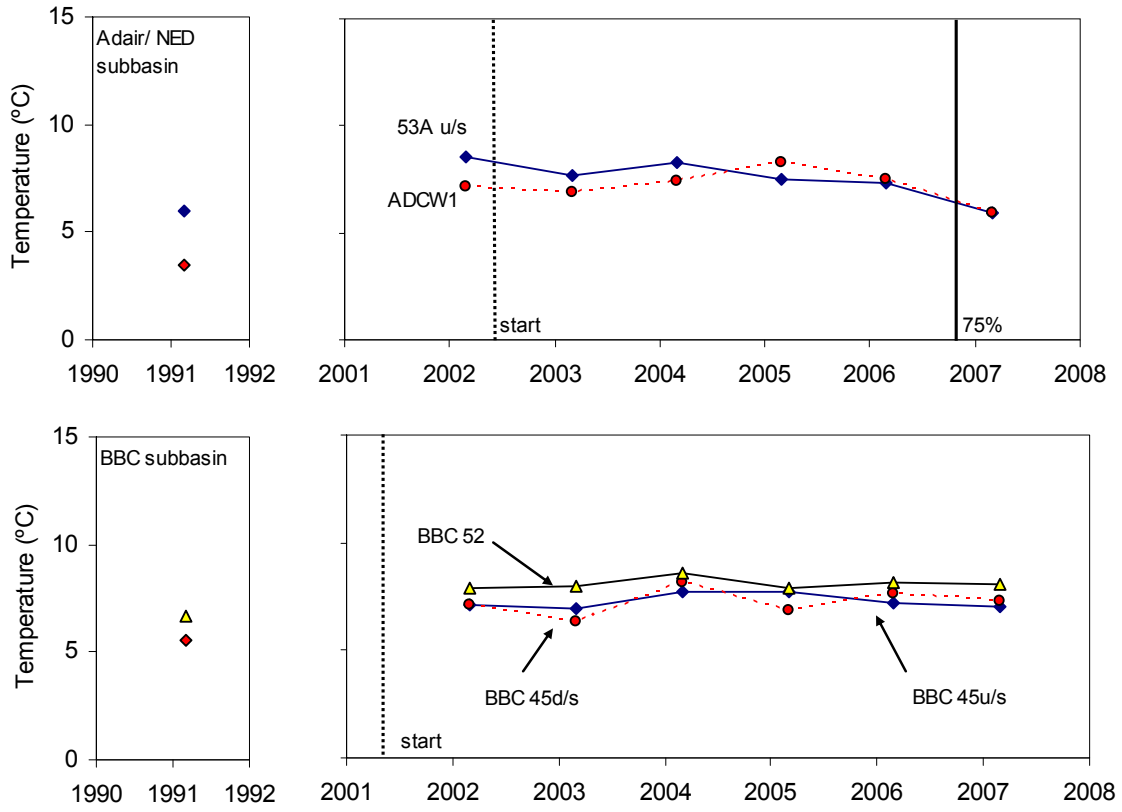

Figure 54. Average annual temperature (1991, 2002-2007).
Data are averages of one to five measurements between January and April each year. Each graph represents a subbasin. The vertical dashed line labeled 'start' refers to the year construction and clearing began within the subbasin and the vertical solid line labeled '75%' represents the date when 75 percent buildout was reached within the subbasin. See Figure 52 Location for locations. (Cont'd next page)

[69] Most intense, surface-flow generating storms occur primarily under low temperature conditions.
[70] Where temperature was recorded using more than one instrument including a hydrolab, YSI sonde, or handheld alcohol thermometer, the average of the two or three measurements is reported.
[71] State criteria standards are relative to the 7-day average of the daily maximum temperatures. Therefore, continuous temperature data, which is presented in a separate results section are more appropriate for comparison to state standards.

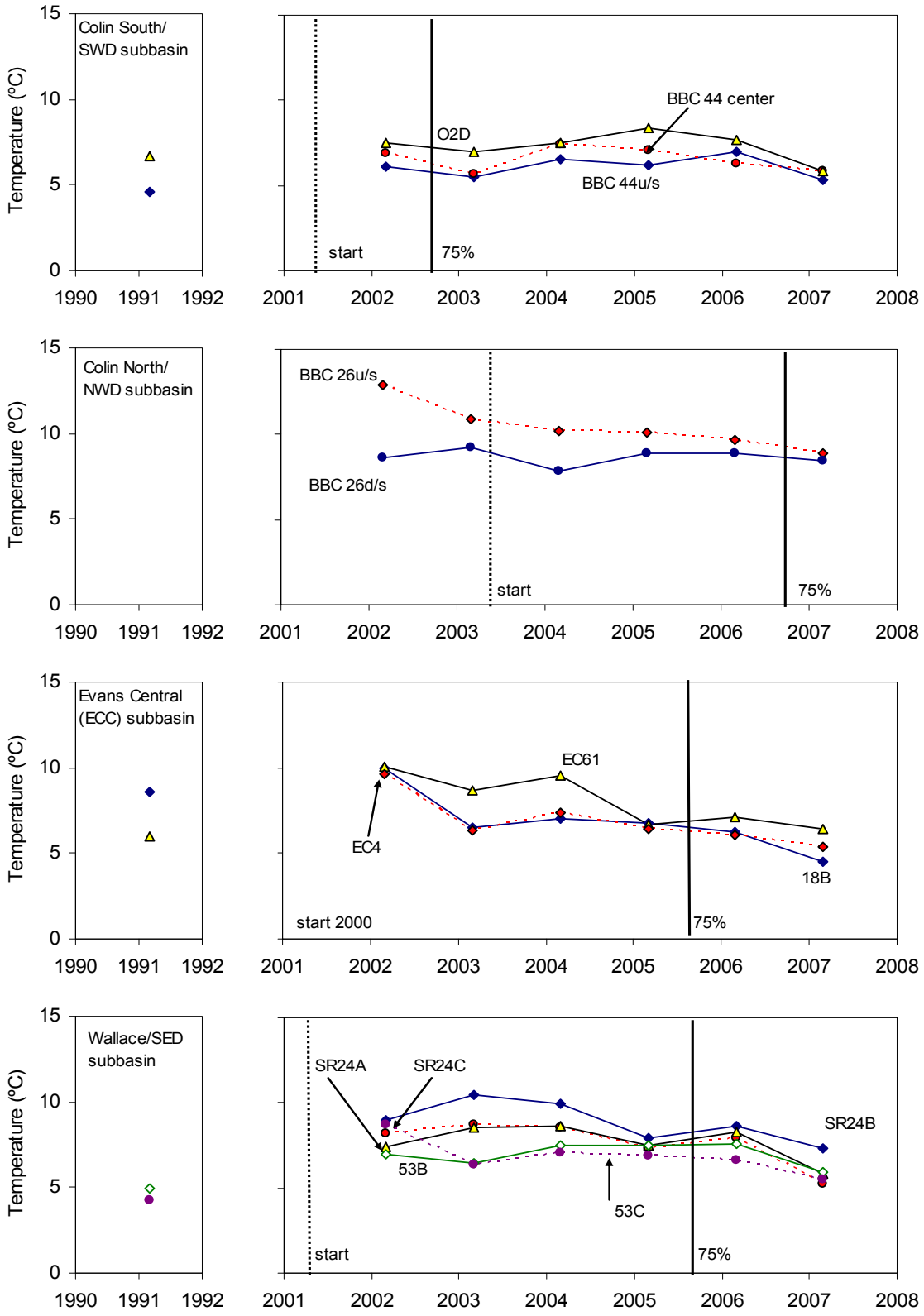

Figure 54 (Cont'd). Average annual temperature. (Cont'd next page)

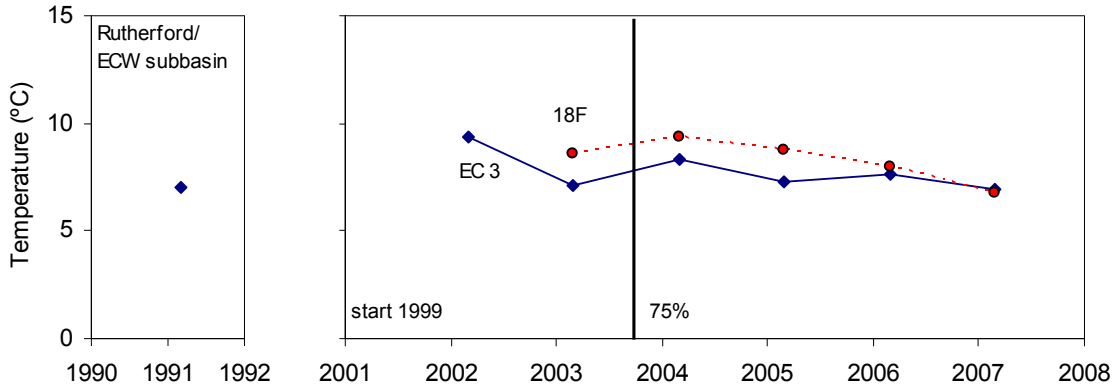

Figure 54 (Cont'd). Average annual temperature.

<u>pH</u>

The 20 monitored streams and wetlands generally all have acidic conditions, with mean annual pH ranging from 5.2 to 7.3 (Figure 55). Mean annual pH has exceeded neutral (above 7) on only four occasions: at Wallace Creek West (53B) in 2005 and at Adair Creek headwaters (ADCW1), wetland EC-3, and Rutherford Creek (18F) in 2006. The mean annual pH values are comparable to the regional median of 6.4 (max = 7.7) calculated for 162 non-urban wetlands (Horner et al. 2001a) and to pH levels found in *Sphagnum*-dominated peatlands that are naturally acidic (Kulzer et al. 2001). However, the stream pH values are frequently below the 6.5 to 8.5 state water quality standard for salmonid migration and rearing streams (Washington Department of Ecology 2006) (Table 27). Overall, the pH within each monitored stream and wetland has remained consistent with peaks typically observed in 2005 (e.g., Wallace Creek – 53B and 53C) or 2006 (most sites) and a return in 2007 to values observed between 2002 and 2004 (Figure 55).

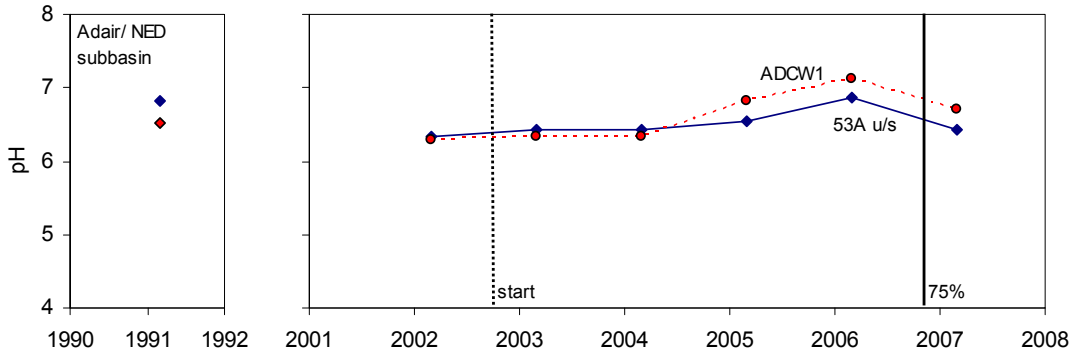

Figure 55. Average annual pH (1991, 2002-2007).
Data are averages of one to five measurements between January and April each year[72]. Each graph represents a subbasin. The vertical dashed line labeled 'start' refers to the year construction and clearing began within the subbasin and the vertical solid line labeled '75%' represents the date when 75% buildout was reached within the subbasin. See Figure 52 for locations. (Cont'd next page)

[72] 2002-2006 were originally recorded with pH paper and corrected to approximate hydrolab readings (multiplied by 1.242, the slope of the line explaining the linear relationship between the pH paper and hydrolab readings). 2007 data were recorded using the Hydrolab.

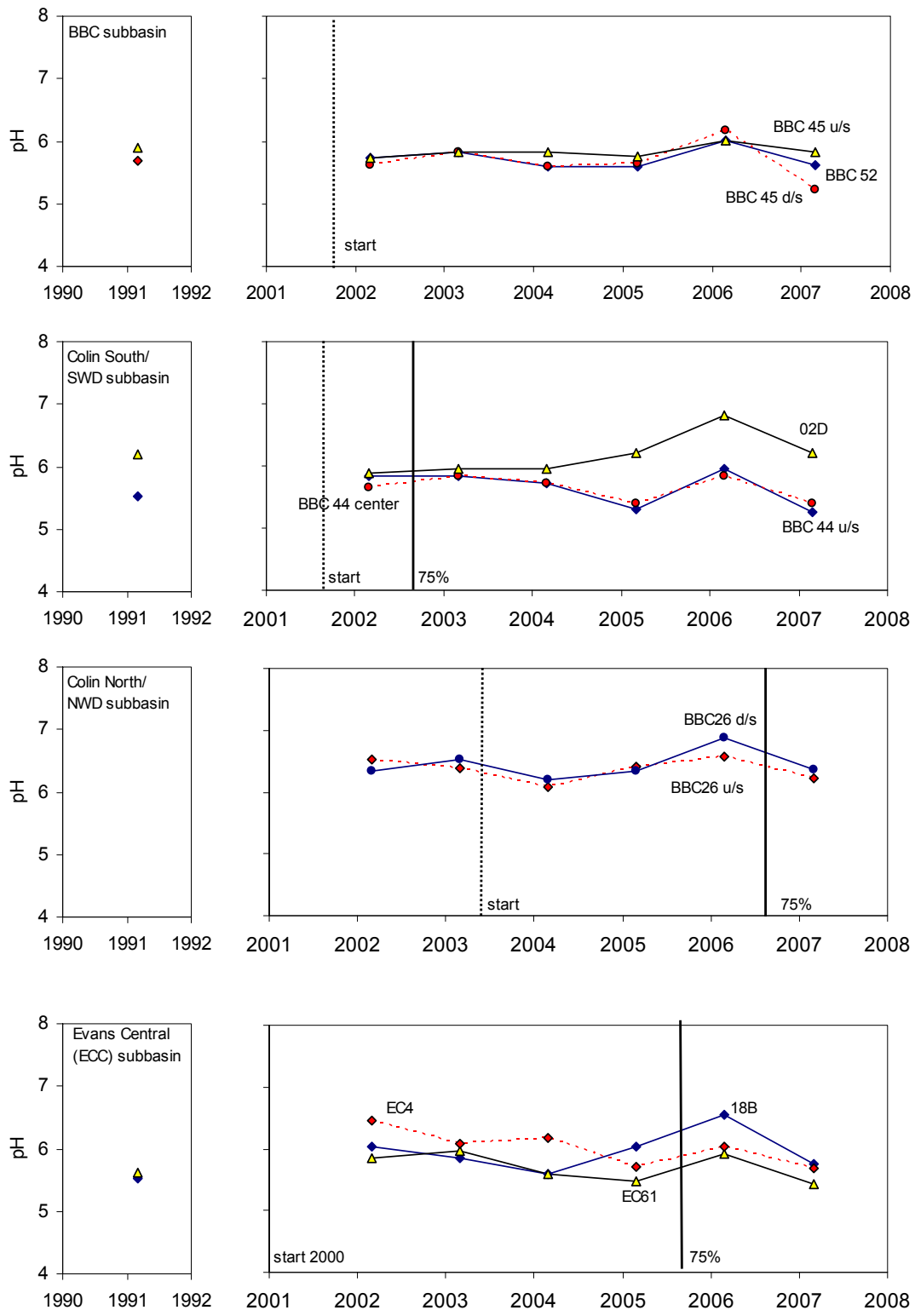

Figure 55. (Cont'd) Average annual pH.

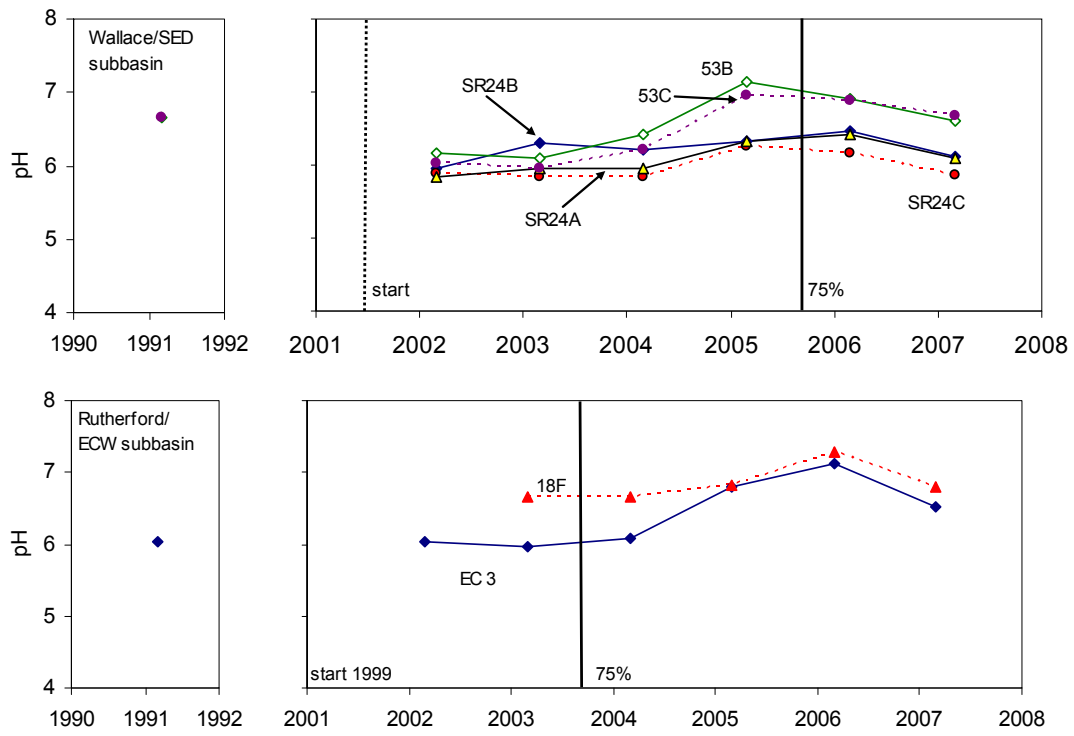

Figure 55. (Cont'd) Average pH.

Table 27. 2007 stream pH measurements below state criteria of 6.5.
Department of Ecology establishes the criteria (Washington Department of Ecology 2006).

Site ID	Date	pH
18B, Evans Creek Central	1/31/2007	5.7
02D, Colin Creek South	2/1/2007	6.1
53A, u/s; Adair Creek	2/1/2007	6.3
18B, Evans Creek Central	2/26/2007	6
02D, Colin Creek South	2/27/2007	6.4
18B, Evans Creek Central	4/30/2007	5.5
02D, Colin Creek South	5/1/2007	6.2
53A, u/s; Adair Creek	5/1/2007	6.4

See Appendix P for 2002-2007 stream pH measurements relative to state criteria.

Alkalinity and Hardness

Alkalinity, a function of carbonate, bicarbonate, and hydroxide content, is a measure of the acid-neutralizing capacity of a water sample. Hardness measures the concentration of multivalent cations, particularly calcium and magnesium, present in a water sample. Increases in hardness or alkalinity, particularly in the wetlands, may signal early chemistry changes that can alter the buffering equilibrium and kill *Sphagnum* moss and shift the wetland away from bog and bog-like characteristics. There are no state standards for alkalinity or hardness.

Data at the UPD water quality sites is limited to 1990, 1991, 1992, 2006, and 2007 for hardness and 2006 and 2007 for alkalinity. Hardness at all water quality sites falls within the low end of the 0-60 mg $CaCO_3$/L 'soft' classification (Durfor and Becker 1964). Between 1990-1992 and 2006-2007 hardness appears to have increased at five sites (53A, ADCW1, EC3, 53B, 53C), decreased at five sites (BBC-52, BBC-45d/s, BBC-44u/s, 02D, EC-61), and remained about the same at one site (18B) (Figure 56). Increases and decreases are generally small in magnitude (less than 6 mg $CaCO_3$/L which is within the intra-annual variability range that varies from 1 to 14 mg $CaCO_3$/L depending on the sampling site). However, hardness levels at EC-3 more than doubled between 1991 and 2006 or 2007 (from ~ 15 to 30 mg $CaCO_3$/L). This coincides with the increasing conductivity trends observed at this site (Figure 53).

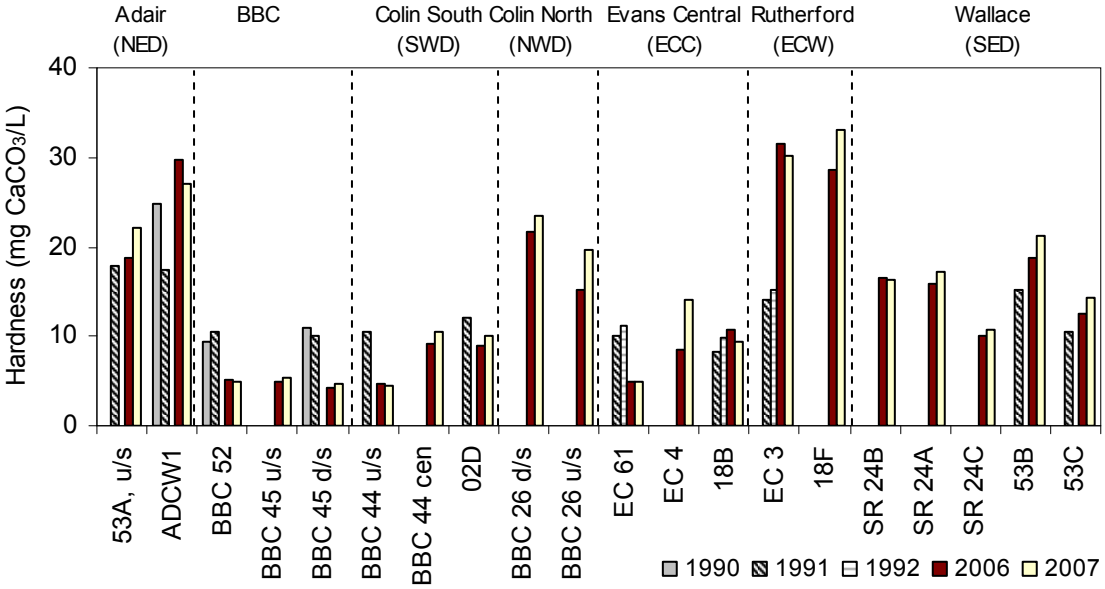

Figure 56. Hardness measurements for UPD water quality sites (1991, 2006- 2007).
Data are averaged from one to five measurements between January and April each year. The dashed vertical lines separate the subbasins. See Figure 52 for locations. Data were only collected in a subset of locations in 1991.

Mean annual alkalinity was highest at wetland EC-3 and Rutherford Creek (18F) within the ECW subbasin with mean values ranging from 34 to 43 mg $CaCO_3$/L. Alkalinity was less than 30 mg $CaCO_3$/L at all other sample sites. Alkalinity appears to have declined between 2006 and 2007 (Figure 57); however, this decrease may represent natural year-to-year variability, as there is a close relationship between total alkalinity concentrations and streamflow.

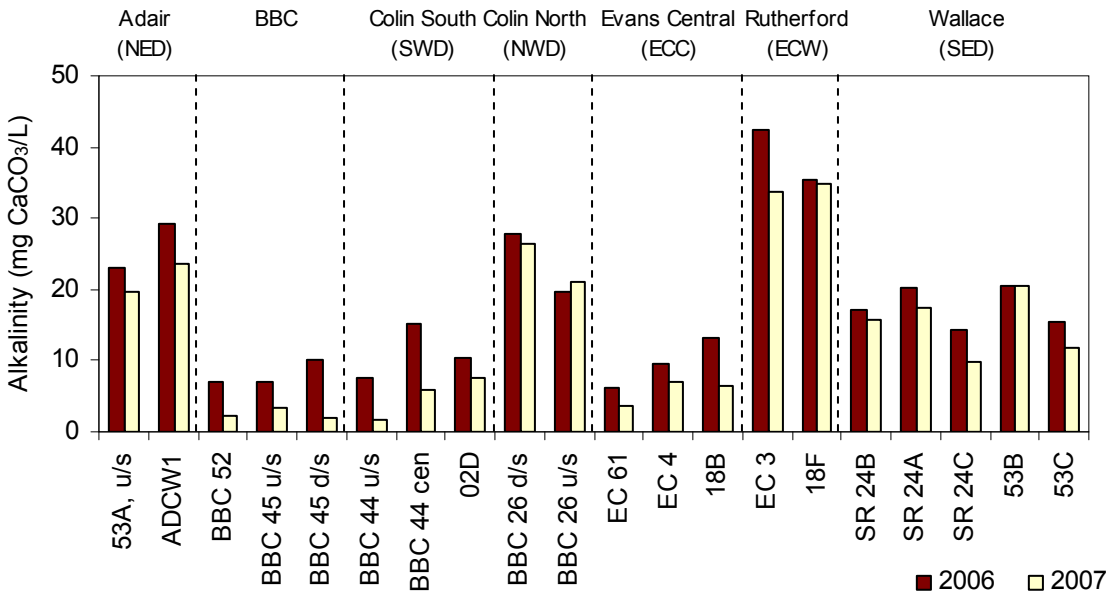

Figure 57. Alkalinity measurements for UPD water quality sites (2006-2007).
Data are averaged from three measurements between January and April each year. The dashed vertical lines separate the subbasins. See Figure 52 for locations.

Other Parameters

Dissolved oxygen, turbidity, and metals were not required by the Trilogy and Redmond Ridge monitoring plans for January through April sampling (King County 1999, 2001). Data that were collected will be used to inform future sampling, where appropriate, and are reported in Appendices R, S, and T.

Continuous Sampling

Temperature and turbidity are the only two parameters sampled in the continuous sampling portion of the monitoring program.

Temperature

Continuous temperature sampling at Adair, Colin North, Colin South, Rutherford, and Wallace West Creeks generally follow the same annual pattern with cooler winter temperatures of less than 5ºC and warmer summer temperatures exceeding 15ºC (See Figures 59-63 and Appendix U). Washington State water quality criteria for salmonid rearing and migration streams are violated if the 7-day average of the daily maximum (7-DADMax) exceeds 17.5°C (63.5°F) (Washington Department of Ecology 2006). Table 28 summarizes violations of these temperature criteria. Temperatures at Wallace Creek West only violated these criteria in 2004. In contrast, temperatures at Rutherford Creek violated these criteria every year that gage data were available[73]. In 2007, violations were observed at Rutherford and Adair Creeks. Large open water wetlands are at the headwaters of Colin South, Colin North, and Rutherford Creeks less than 500 m upstream of the water quality monitoring location. These wetlands naturally contribute to increased summer maximum temperatures due to increased residence time of water and the large surface areas exposed to solar radiation prior to its release downstream.

[73] See Figures 59-63 for available data. Most gages had technical problems during summer 2006.

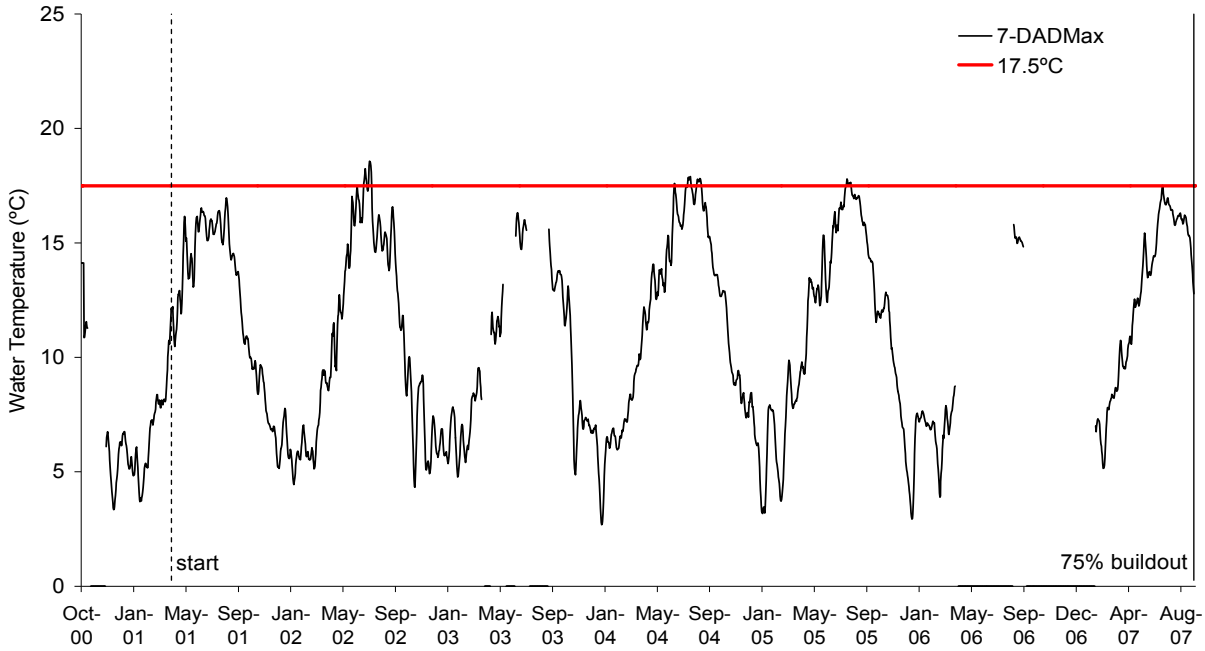

Figure 58. Maximum 7-day average daily temperature (7-DADMax) for Adair Creek (2000-2007).
Data from gage 53A. 17.5ºC is the state standard for salmon migration and rearing streams. UPD construction commenced in late spring/early summer 2002 ('start') and 75% buildout was reached in September 2007.

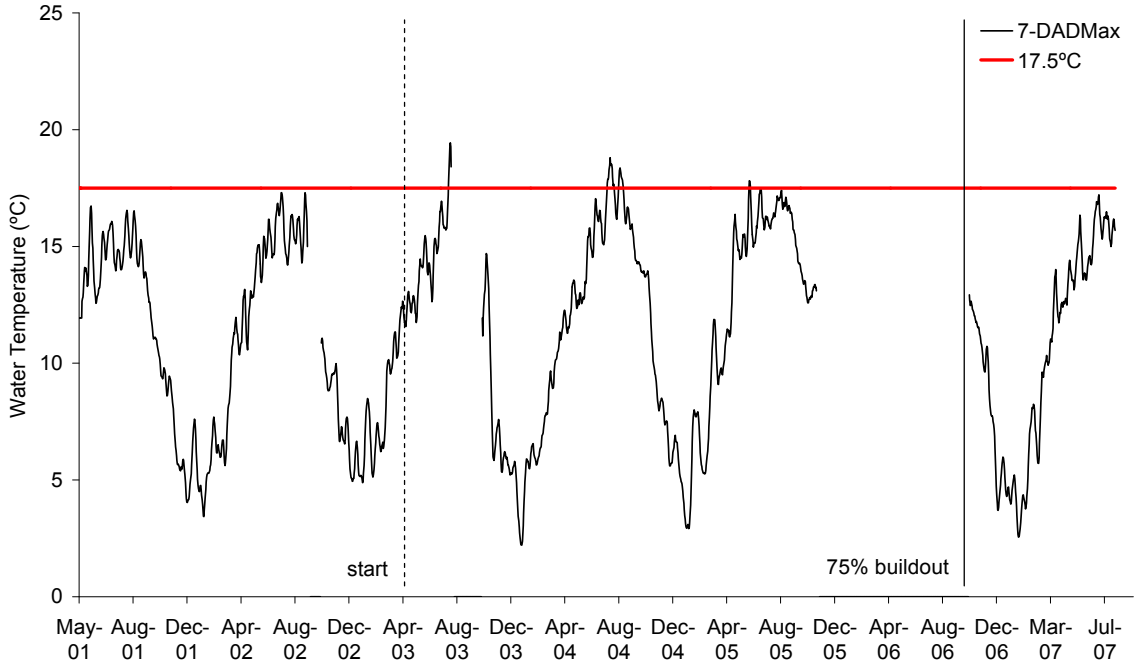

Figure 59. Maximum 7-day average temperature for Colin Creek North (2001-2007).
Data from gage 02C. 17.5ºC is the state standard for salmon migration and rearing streams. UPD construction commenced in late spring/early summer 2003 ('start') and 75% buildout was reached in October 2006.

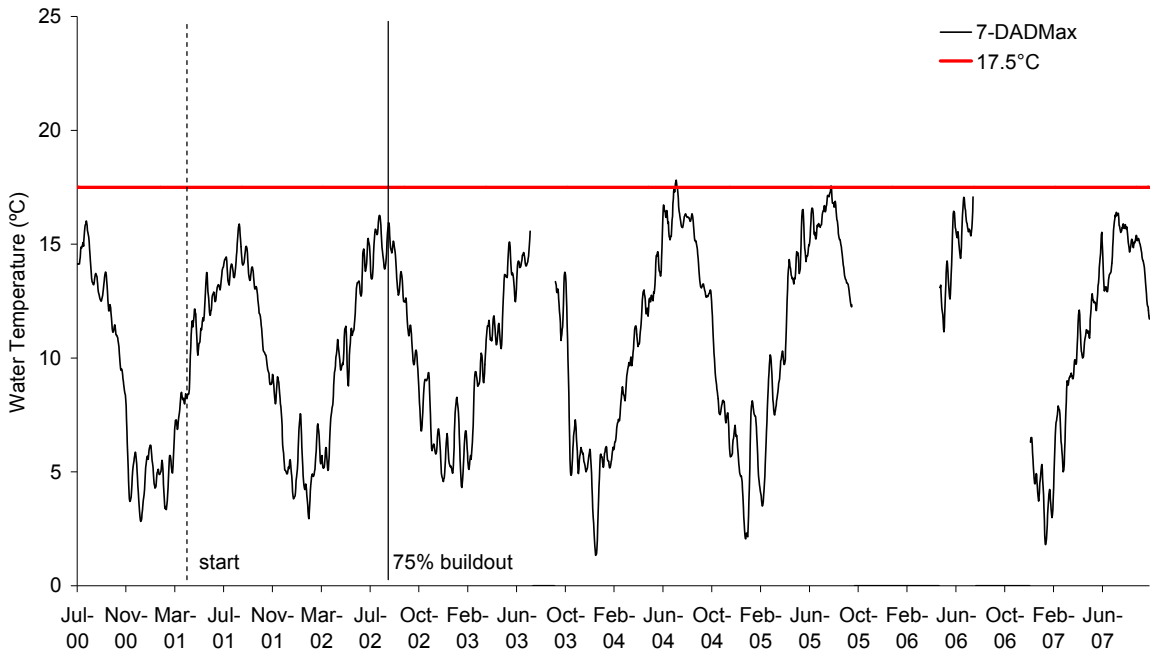

Figure 60. Maximum 7-day average daily temperature (7-DADMax) for Colin Creek South (2000-2007). Data from gage 02D. 17.5ºC is the state standard for salmon migration and rearing streams. UPD construction commenced in late spring/early summer 2001 ('start') and 75% buildout was reached in August 2002.

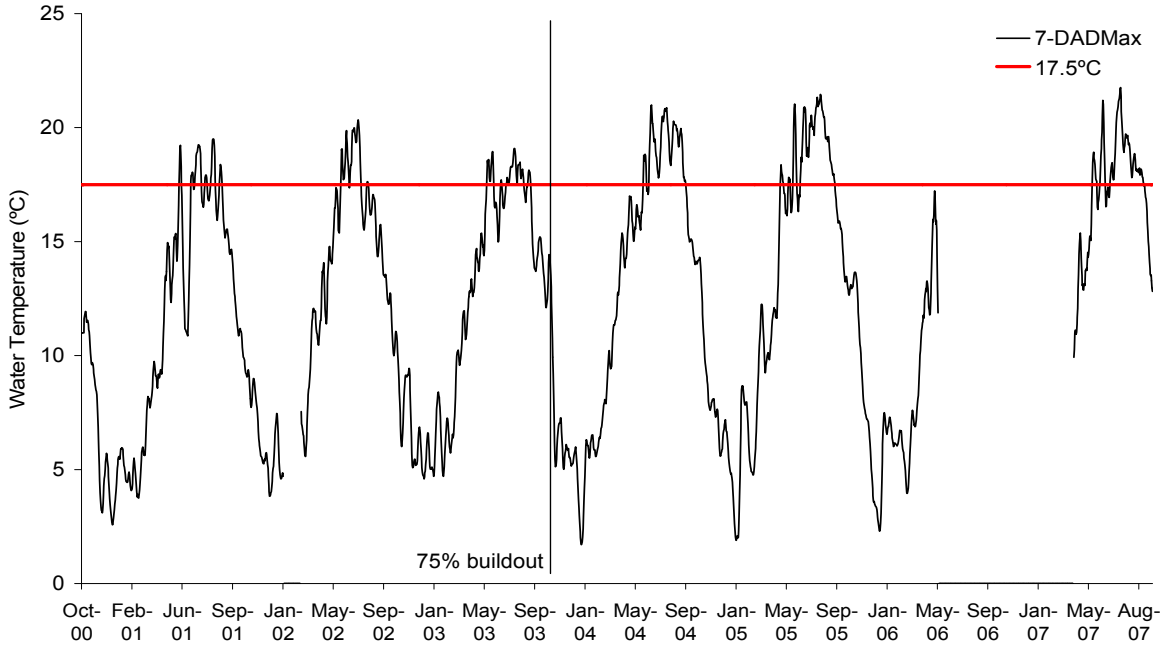

Figure 61. Maximum 7-day average daily temperature (7-DADMax) for Rutherford Creek (2000-2007). Data from gage 18F. 17.5ºC is the state standard for salmon migration and rearing streams. UPD construction commenced in late spring/early summer 1999 ('start') and 75% buildout was reached in October 2003.

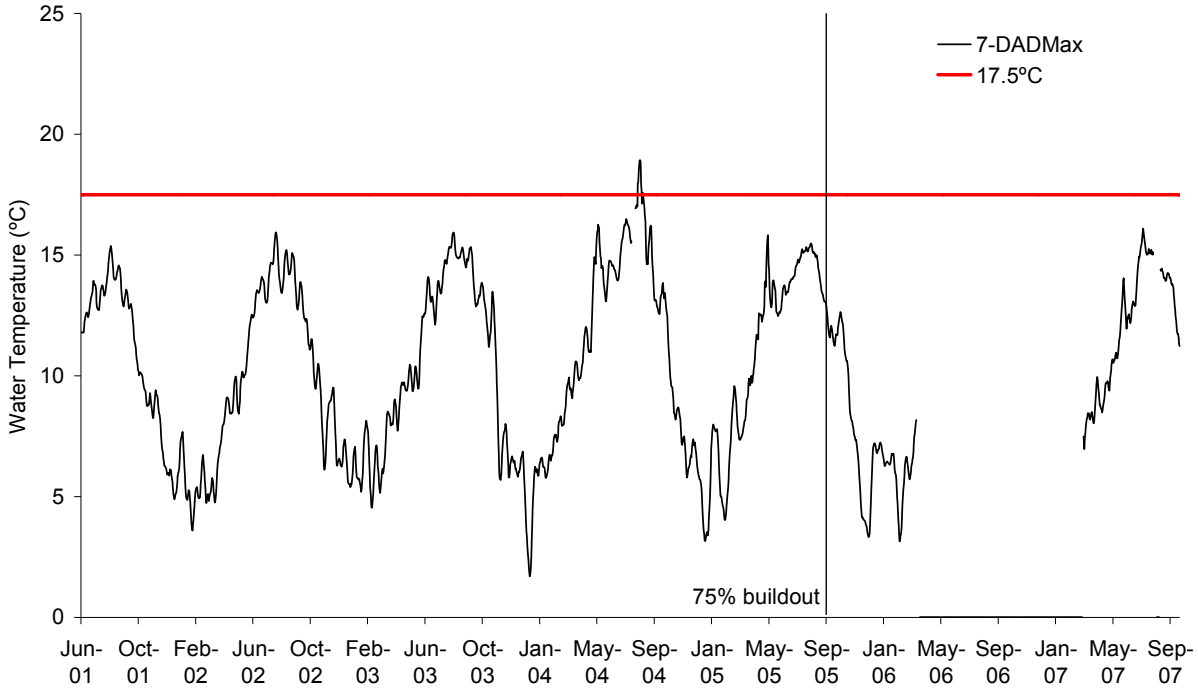

Figure 62. Maximum 7-day average daily temperature (7-DADMax) for Wallace Creek West (2001-2007). Data from gage 53B. 17.5ºC is the state standard for salmon migration/rearing streams. UPD construction commenced in late spring/early summer 2001 and 75% buildout was reached in September 2005.

Table 28. Stream temperature exceedances of state criteria.
Annual maximum temperatures measured as 7-day average daily temperature (7-DADMax) and dates that violate the state criteria of 17.5ºC. (Cont'd next page).

Year	7-DADMax 17.5ºC Exceedance Dates	Annual Max 7-DADMax Temperature (ºC)
Adair (53A)		
2002	July 12-19; July 23-29	18.6
2004	July 23; July 23-30; Aug 13-23	17.9
2005	July 22-Aug 1	17.8
2007	July 16	17.5
Colin North (02C)		
2003	July 31-Aug 6	19.3
2004	July 18-Aug 2; Aug 13-22	18.8
2005	May 29-June 1; June 24;	17.8
Colin South (02D)		
2004	July 22-25	17.8
2005	Aug 9	17.6

Table 28. (Cont'd) Stream temperature exceedances of state criteria.

Year	7-DADMax 17.5ºC Exceedance Dates	Annual Max 7-DADMax Temperature (ºC)
Rutherford (18F)		
2001	May 25-29; June 21-27; June 30-July 16; July 25-July 29; Aug 7-18; Aug 28-Sept 3	19.5
2002	June 14-July 3; July 5-July 31; Aug 15-18	20.0
2003	May 27-June 13; June 30-July 2; July 14-23; Sept 3-9	18.9
2004	June 3-11, June 17-Sept 12	21.0
2005	April 27-May 3; May 15-19; May 26-June 4; June 13-Sept 3	21.4
2007	May 10-20; May 28-June 9; June 21-Sept 9	21.8
Wallace West (53B)		
2004	Aug 22-30; Sept 2	18.9

Turbidity

Results for continuous turbidity sampling were difficult to interpret because of problems with equipment fouling. Appendix S displays the results of the turbidity monitoring, which was ceased in 2005.

Threshold Exceedance Criteria and Evaluation

Exceedance criteria for January through April wetland and stream water quality are violated if:

1. There are negative deviations from baseline conditions significant to wetland or stream function (pH, temperature, specific conductivity).
2. There are extreme fluctuations in measurements signaling system instability or unusual inputs.
3. Alkalinity differs from predevelopment alkalinity (King County 2001).

Specific conductivity appears to be increasing at several sampling locations, possibly signifying negative deviations from baseline conditions. There were no extreme fluctuations observed for pH, temperature, or specific conductivity. No predevelopment alkalinity data were collected for comparison to post-development conditions. However, hardness and alkalinity were highly correlated in 2006 and 2007 ($r^2 = 0.81$), and hardness does appear to be increasing at several sampling locations in 2006 and 2007 relative to 1991.

Continuous stream water quality threshold exceedance criteria are violated if:

1. Water quality degradation is observed including changes from baseline temperature, turbidity, pH, or other conditions.
2. State and federal water quality standards are violated.

7-day maximum mean temperatures have exceeded the state standards of 17.5°C (63.5°F) for salmonid rearing and migration streams (Washington Department of Ecology 2006) at least once

during the summer months at all five monitored streams: Wallace Creek West in 2004, Colin Creek South in 2004, Colin Creek North in 2003, 2004, and 2005, Adair Creek in 2002, 2004, and 2006, and Rutherford Creek in every year the recording equipment was functioning (2001 to 2005 and 2007). All five sampling locations are within 500-m (0.3 miles) of open water wetlands where the ponded water is expected to be warmer.

Turbidity measurements were discontinued because of equipment fouling problems. pH measurements lower than the state standards of 6.5 are likely due to the fact that the streams drain from headwater wetlands that are naturally very acidic. Therefore, the low pH values are potentially not linked to UPD development.

Corrective Actions

As a result of the gaps in information, a detailed understanding is not possible of the natural predevelopment variability in most field parameters. Continuous stream temperature monitoring should be watched closely for any increasing trends over time. Exceedances of state standards for temperature and pH are not unexpected because of the location of the recording gages downstream from acidic, open water wetlands. The apparent increases in conductivity and hardness across several wetland and stream locations warrant further investigation. However, no corrective actions are recommended pending the results from facility water quality performance monitoring scheduled to be implemented in water year 2008.

3.11 Welcome Lake Trophic State

Welcome Lake is located off-site and downstream from the Trilogy and Redmond Ridge UPDs to the northwest and is the only lake that could potentially be impacted by these developments (Figure 4). Approximately 700 acres (283 ha), i.e., about half of the Welcome Lake drainage lies within either the Trilogy or Redmond Ridge UPD (King County 2001). It is an artificial lake created in 1960 by construction of a 20 ft (6.1 m) tall earth-filled dam at Weymouth Pond, which was later rebuilt in 1986 (Shapiro and Associates Inc. 1984, Herrera Environmental Consultants Inc. 1992, Beak Consultants Incorporated 1995). The lake is approximately 14 acres (5.7 ha) in size, has a mean depth of approximately 10 ft (3 m) (Sumioka 1985), and drains approximately 1,433 acres (580 ha) (Hugh G. Goldsmith and Associates 1996).

The lake's threshold eutrophic trophic status index (TSI) classification (Carlson 1977) prompted concerns in the mid-1990s over potential increases in phosphorus levels from urbanized upstream sources that might push a sensitive Welcome Lake into the eutrophic category. These concerns resulted in lake monitoring requirements being included as part of the UPD permits (King County 1993). UPD construction within the Welcome Lake subbasin began in 2001 (Otak Incorporated 2006), with 75 percent buildout estimated to have occurred in June 2006 (Lowe 2005, 2008).

See Appendix V for details of Welcome Lake sampling through 2007.

Modifications

Monthly water quality monitoring between June through September for total phosphorous, total nitrogen, chlorophyll-a, and Secchi depth was slated to begin following 75 percent buildout (i.e., 2006) in the basins that drain to the lake. However, since 1996 these parameters have been

monitored biweekly between May through October by volunteers recruited through the King County Lake Stewardship Program within the Department of Natural Resources and Parks, and the data are available for analysis.

Sampling Recommendations – Continue with annual monitoring (see Appendix V). If the Lake Stewardship Program is unable to continue to support Welcome Lake monitoring, King County WLRD should take over responsibility until the required monitoring duration is met.

Procedures

Water quality data are collected at biweekly intervals from May through October at 3.3 ft (1 m) of depth from the middle of Welcome Lake. Data collected include Secchi transparency, temperature, chlorophyll-a, total phosphorus and total nitrogen. Ideally, each parameter is measured at the same time of day each time it is collected.

Secchi depth and water temperature are measured over the lake's deepest point (Wolcott 1964, United States Geological Survey (USGS) 1976) from an anchored boat. For Secchi depth, the 8 in (20.3 cm) diameter disk is lowered over the shaded side of the boat until the disk disappears from view. The disk is then lifted until it reappears again. The depth of disappearance and reappearance are recorded and if different they are averaged. For temperature, a slow changing Celsius thermometer is submerged to a depth of 3.3 ft (1 m) below the water surface for 2 minutes. Temperature is recorded to the nearest 0.5 degree.

Water samples are collected from 3.3 ft (1 m) depth using a Van Dorn vertical water sampler 12 times a season from early May through October (at 2-3 week intervals). Water is saved in containers for analysis of total phosphorous, total nitrogen, and chlorophyll-a.

Sample bottles are kept on ice until they are delivered to the EPA-approved KCEL, where strict protocols for sample handling and quality assurance of chemical analysis are followed. These protocols include analyzing blanks and predetermined standards to check accuracy and precision of the analysis.

The mean Trophic State Index (TSI) is calculated for May-October of each year and examined for trends over time[74]. The TSI separates lakes into oligotrophic, mesotrophic, and eutrophic categories by scoring summer mean water clarity and concentrations of phosphorus and chlorophyll-a and placing the values on a scale related to phytoplankton biovolume (Carlson 1977). Every 10-point division (e.g., 10, 20, 30, etc.) represents a doubling of algal biovolume calculated by linear regression and re-scaling of the three parameters above. Values over 50 represent highly productive, eutrophic lakes; between 40 and 50 are moderately productive, mesotrophic lakes; and less than 40 are low productivity, oligotrophic lakes.

Results

Based on the average of Secchi depth, chlorophyll-a, or total phosphorous, Welcome Lake has a TSI score in the eutrophic range in 1996 and in the mesotrophic range every year from 1997 to

[74] The TSI can be calculated from any of several parameters including Secchi disk transparency, chlorophyll a, and total phosphorous (Carlson 1977). For this report the TSI is also calculated from the average of the individual Secchi, chlorophyll a, and total phosphorous TSIs.

2007 (Figure 63). Over the period of measurement it has slowly declined towards the middle of the mesotrophic range.

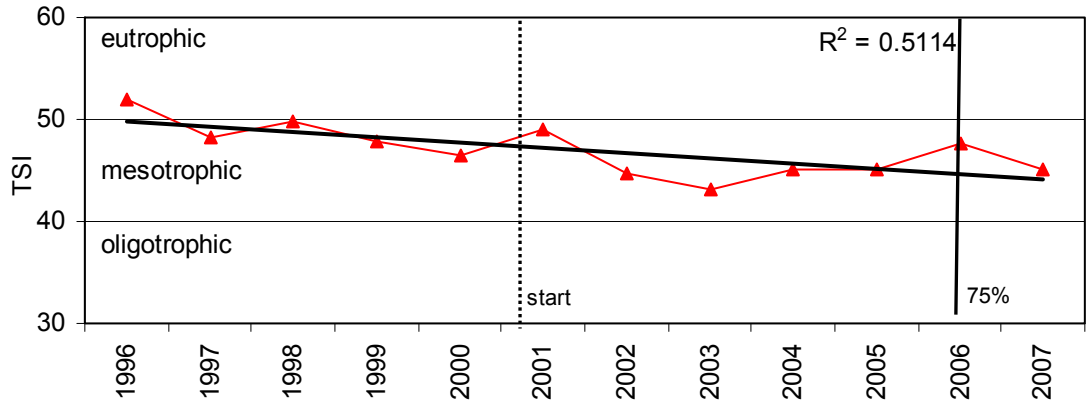

Figure 63. Welcome Lake trophic state index (TSI) averaged from Secchi depth, chlorophyll-a, and total phosphorous TSI scores (1996-2007).
Welcome Lake was sampled bimonthly between May and October 1996 to 2007 near the middle of the lake at 3.3 ft (1-m) depth. The dashed vertical line represents the start of construction (April 2001) and the solid vertical line 75% buildout (June 2006) within the Welcome Lake subbasin.

Chlorophyll-a values were in the eutrophic range in 1996, 1998, 1999, and 2001, and total phosphorus was in the eutrophic range in 1996 and 1997 (Figure 64). The chlorophyll-a concentrations have had the highest year-to-year variability, a trend that has also been noted at other lakes around King County and may be influenced by the many factors affecting algal concentrations including patchiness from wind and water movement, changes in species compositions, and differences in chlorophyll concentration for different species (King County 2006).

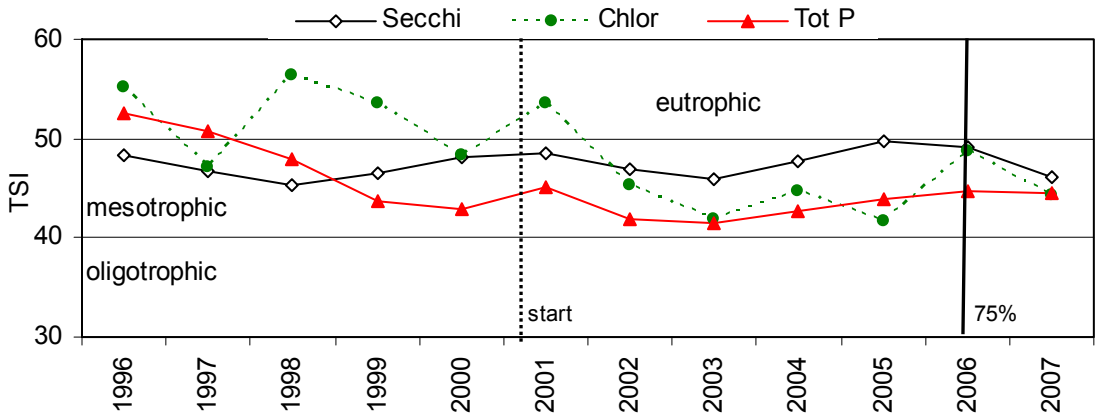

Figure 64. Welcome Lake trophic state index (TSI) of three parameters: Secchi depth, chlorophyll-a (Chlor), and total phosphorous (Tot P) (1996-2007).
Data are averaged from bimonthly samples between May and October 1996 to 2007 for Welcome Lake. Samples were collected near the middle of the lake at 3.3 ft (1-m) depth. The dashed vertical line represents the start of construction (April 2001) and the solid vertical line 75% buildout (June 2006) within the Welcome Lake subbasin.

See Appendix W for additional Welcome Lake results and Appendix X for raw 2006-2007 Welcome Lake water quality data.

Threshold Exceedance Criteria and Evaluation

Welcome Lake threshold exceedance criteria are violated if there is a change in the trophic state of the lake above the levels predicted in the Drainage Master Plan (DMP) (King County 2001). The DMP predicted that the TSI might change from predevelopment levels of 54 to a maximum of 56, but this change was not expected to have a significant effect on the Welcome Lake trophic condition (Herrera Environmental Consultants Inc. 1995). 2007 was the first full year after the 75 percent buildout threshold, and the TSI was 45. This TSI is lower than the pre-UPD construction range of 46.5 (2000) to 52.0 (1996). Therefore, Welcome Lake appears not to have become more eutrophic, in contrast to the DMP prediction.

Corrective Actions

No corrective actions are recommended for this component of the monitoring plan.

3.12 Sediment Analysis

Sediment monitoring is important for assessing overall environmental quality and the cumulative effects of urban runoff and non-point pollution sources, because most contaminants accumulate over time in the sediments, not the water column (Horner et al. 1994, Dillon et al. 1997). Therefore, analysis of sediments is useful for determining existing and historical water quality conditions. The Redmond Ridge monitoring plan calls for annual sediment metals analysis at Rutherford and Colin South Creeks (King County 1999) (Figure 65).

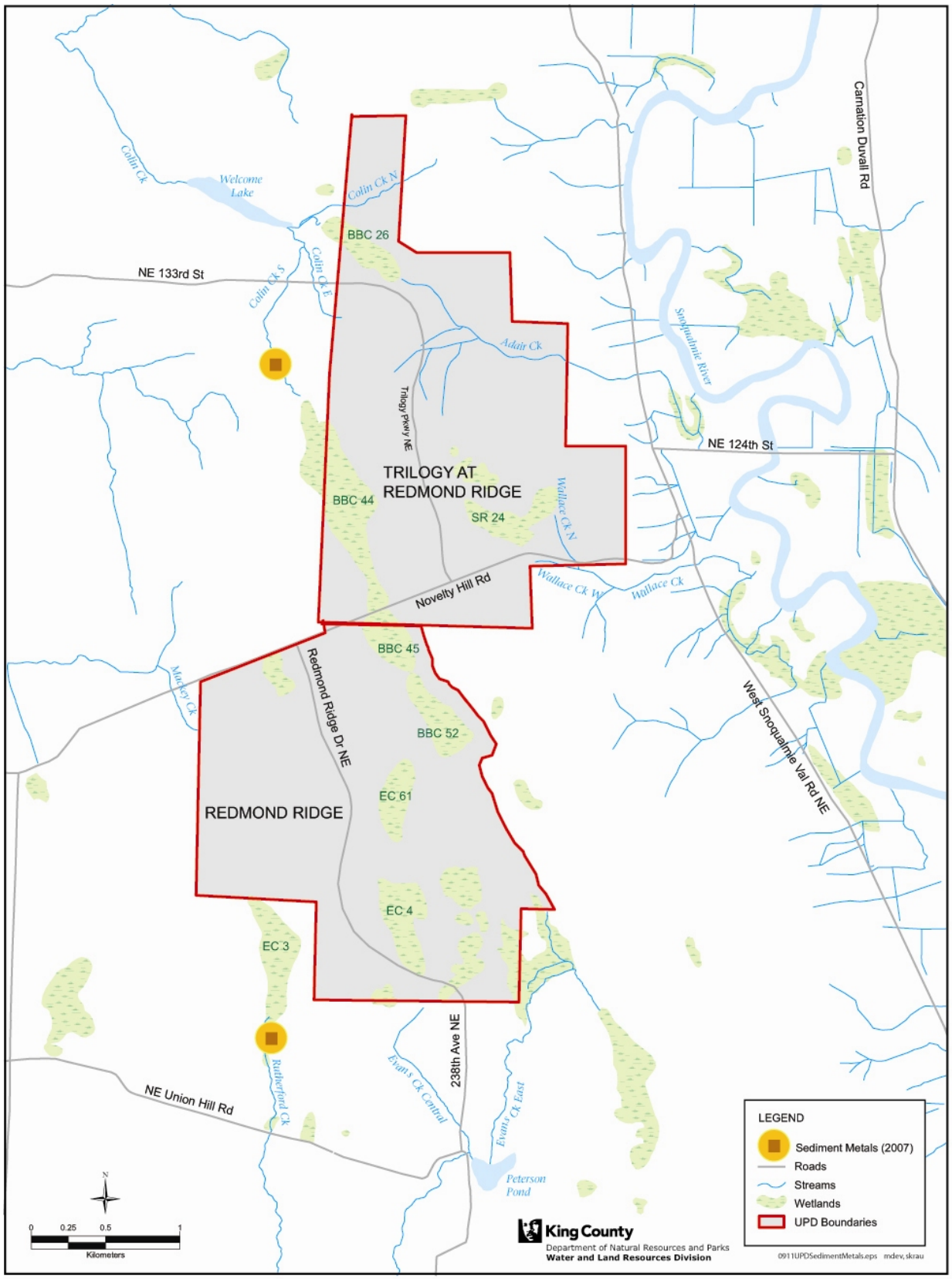

Figure 65. Sediment metals sampling locations.
Sediment metals were sampled at Rutherford and Colin South Creeks in 2007.

Modifications

The Redmond Ridge monitoring plan calls for sediment metals sampling beginning in the first year of construction continuing through 3 years after 75 percent buildout in the Rutherford and Colin South subbasins (King County 1999). The monitoring schedule was modified at both locations with sampling taking place in 1998-2000 and for three years post 75% buildout in 2005-2007[75] (see Appendix Y for sampling schedule). Sediment analysis is not identified as a required parameter in the Trilogy monitoring plan (King County 2001)[76].

Only metals are required for sediment analyses; however, analyses of organic contaminants were conducted during 1991, 2005, and 2006, and phthalates testing was conducted in 2005. Only metals data will be presented in this report, but see the Midpoint Report for organics and phthalates results (King County 2006).

Sampling Recommendations – 2007 was the third year of sediment sampling following 75% buildout in both Rutherford and Colin South subbasins. Therefore, the sediment sampling elements of the monitoring plans have been fulfilled and no further sampling is required or recommended.

Procedures

Sampling takes place under summer low flow conditions before the onset of the rainy season in September or October each year at Rutherford and Colin South Creeks (Figure 65). Methods varied slightly over the sampling period. During 1998-2000, sampling was conducted as follows: five 6.8 oz (200 mL) subsamples were collected from the top 4 in (10 cm) of streambed and composited into one sample mixed in a plastic bucket with a wooden stirring rod to avoid metals contamination. Larger cobble and gravel were removed before transferring the homogenized slurry into sample jars.

From 2005 onward sampling has been conducted by King County WLRD scientists using procedures outlined in the Stream Sediment Sampling and Analysis Plan (King County 2004). Approximately 15 sediment grabs 2-4 in (5-10 cm) deep are collected from depositional areas in shallow water (<2 ft (61 cm) deep) at each site using pre-cleaned[77] PVC core tubes (2.8 in (7 cm) diameter x 36 in (91.4 cm)) with tapered edges to form a penetrating edge. A stainless steel spatula or gloved hand is inserted under the mouth of the core tube to trap sediment and the tube is angled to allow excess water to drain without losing any fine material. The sample is transferred into a stainless steel bowl where it is composited with other subsamples and stirred with a stainless steel spoon. Rocks and other debris greater than 0.5 in (1.27 cm) in diameter are removed and the homogenized slurry is transferred to the pre-labeled laboratory-supplied sample jars. New core tubes, bowls, spoons, spatulas, and sample jars are used between sites to ensure no cross-site contamination occurs.

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[75] Following the monitoring plan schedule, Rutherford Creek would have been sampled 1999-2006 (construction started in 1999 and 75% buildout was in October 2003) and Colin Creek South would have been sampled 2001-2005 (construction started in 2001 and 75% buildout was in August 2002).

[76] Though not technically required, Adair and Wallace were sampled in 1991 and annually from 1998-2000 (see Comings et al. (2000, 2001a) for results).

[77] PVC tubes are pre-cleaned with Detergent 8 at KCEL, soaked in a 5% acid solution, and rinsed with de-ionized water. Both ends of the tubes are covered with foil after air drying.

Samples are transported to the KCEL at the end of each sampling day. Standardized analytical protocols and associated QA/QC guidelines are followed for all chemical analyses. See the Midpoint Report (King County 2006) for details on the laboratory methods for analyses.

1998 data were recorded as wet weight and all other data were reported as dry weights. The total solids data were used to convert 1998 wet weight data into dry weight[78].

Results

Cadmium, copper, lead, and zinc were analyzed in all years (Table 29). There were no violations of sediment quality guidelines[79] for these four metals at Colin South or Rutherford Creeks in 2007. For Colin Creek South sediments, 2007 cadmium, copper, lead, and zinc levels, although below guidelines, were elevated relative to other years: cadmium was detected for the first time, and copper, lead, and zinc were nearly twice the concentration of any previous year. For Rutherford Creek sediments, copper, lead, and zinc levels peaked in 2006, but returned to the range of predevelopment concentrations in 2007.

[78] Dry weight = wet weight/(% total solids x 0.01)

[79] Smith et al. (1996) developed guidelines based on threshold effects levels (TEL) that estimate the chemical concentration below which adverse biological effects are rarely expected to occur and probable effects levels (PEL) that estimate the chemical concentration above which adverse biological effects are frequently expected to occur. Department of Ecology also is working to test and establish sediment guidelines (Washington State Department of Ecology 2003).

Table 29. Results of sediment metals analyses compared to sediment guidelines.
PEL - Probable effects level; TEL – Threshold effects level; Ecology – Department of Ecology Guidelines. MDL – Method detection limit (Smith et al. 1996, Washington State Department of Ecology 2003).

	Total solids %	Cadmium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Aluminum (mg/kg)	Arsenic (mg/kg)	Mercury (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)
Ecology		0.6	50	335	140	N/A	20	0.5	55	0.55
PEL		3.53	196.6	91.3	314.8	N/A	17	0.486	35.9	N/A
TEL		0.596	35.7	35	123.1	N/A	5.9	0.174	18	N/A
Colin South	(Construction Start 2001, 75% Buildout August 2002)									
10/22/1998	83.3	< MDL	6.8	4.1^	19.5	7110	NT	NT	NT	NT
10/18/1999	78.7	< MDL	12.4	5.5^	36.7	14500	NT	NT	NT	NT
10/13/2000	72.9	< MDL	9.4	7.4^	38.7	11900	NT	NT	NT	NT
11/1/2005	74.5	< MDL	6.86	11.6	29.7	NT	**12^**	0.03^	14.9	0.27^
9/7/2006	Dry Channel, no sample collected									
9/13/2007	23	0.43^	29.9	23.6	84.8	NT	**37.1**	0.083^	**47.8***	**1.66**
Rutherford	(Construction Start 1999, 75% Buildout October 2003)									
10/22/1998	76.3	< MDL	4.9	3.3^	29.6	6690	NT	NT	NT	NT
10/18/1999	37.1	< MDL	16.2	16^	66.3	20000	NT	NT	NT	NT
10/13/2000	78.9	< MDL	6.8	6.1^	40.6	11600	NT	NT	NT	NT
11/1/2005	76.3	<MDL	5.58	5.5^	25.8	NT	4.7^	0.037^	12.7	0.28^
9/7/2006	10.9	<MDL	21.5	**64^**	94.5	NT	**45^**	**0.34^**	**22^**	<MDL
9/13/2007	52.8	0.18^	5.51	10.5	20.5	NT	**6.34**	0.049^	8.77	0.3^

NT = Not tested
bold - concentration exceeds TEL, but not PEL or Ecology guidelines
bold* - concentration exceeds TEL and PEL, but not Ecology guidelines
bold and underline - Concentration exceeds all existing guidelines (TEL, PEL, and Ecology where applicable)
^ below RDL (reporting detection limits)

Aluminum, arsenic, mercury, nickel, and silver are analyzed in some years, but not all. Arsenic, mercury, nickel, and silver were not tested prior to UPD development to establish baseline conditions. However, arsenic concentrations exceeded sediment guidelines in 2005 and 2007 in Colin Creek South and in 2006 and 2007 in Rutherford Creek (Table 29). Nickel and silver exceeded sediment guidelines in Colin South in 2007; mercury and nickel exceeded sediment guidelines in Rutherford Creek in 2006. There are no established guidelines for aluminum, an abundant naturally occurring metal (Horner et al. 1994) and it wasn't tested for from 2005-2007.

See Appendix Z for 2007 results from KCEL.

Threshold Exceedance Criteria and Evaluation

Stream sediment quality threshold exceedance criteria are violated if degradation compared to baseline stream conditions is observed (King County 1999). Baseline conditions were established only for cadmium, copper, lead, zinc, and aluminum. Copper, lead, and zinc sediment metals concentrations were elevated relative to predevelopment levels at Rutherford Creek in 2006 and at Colin Creek South in 2007.

Corrective Actions

No corrective actions are recommended for this component of the monitoring plan. None of the elevated levels of copper, lead, and zinc exceeded freshwater sediment quality guidelines[80]. In addition, the elevated metals values might be due to changes in the type of microhabitat sampled[81]. Post-development (2005-2007) samples with total solids percentages approximating the predevelopment percentage range had comparable sediment metals concentrations.

3.13 Groundwater Hydrology

The objective of the groundwater hydrology monitoring program is to ensure that groundwater recharge is maintained both during the construction phases and following full buildout of the UPD. Redmond Ridge groundwater hydrology monitoring has been conducted by Associated Earth Sciences, Inc. (AESI) on behalf of Quadrant Corporation since October 1995 (Associated Earth Sciences Inc. 2007b).

Eleven observation wells (OBW) were monitored in water year 2007 to record ground water levels in the Vashon advance aquifer at Redmond Ridge (OBW-1R, -2R, -3R, -4R, -6, -7R, -8, -10, and -11) and Redmond Ridge East (OBW-5 and -12). In addition, one observation well was monitored to record groundwater levels in pre-Vashon age deposits at Redmond Ridge East (OBW-9) and one shallow monitoring well recorded perched groundwater levels within Vashon lodgement till at Redmond Ridge (MW-8) (Figure 66).

[80] There are no sediment quality standards for the State of Washington, however there are freshwater sediment quality guidelines that are used for comparison (Smith et al. 1996, Washington State Department of Ecology 2003).
[81] The Rutherford Creek 2006 sample had only 10.9 percent total solids, whereas all other years had between 37.1 and 78.9 percent; the Colin South 2007 sample had only 23 percent total solids, whereas all other years had between 72.9 and 83.3 percent (Table 29). A lower percentage of total solids represents a 'muddier' sample dominated by silts rather than sands. Contaminants are more likely to bind to finer silt particles.

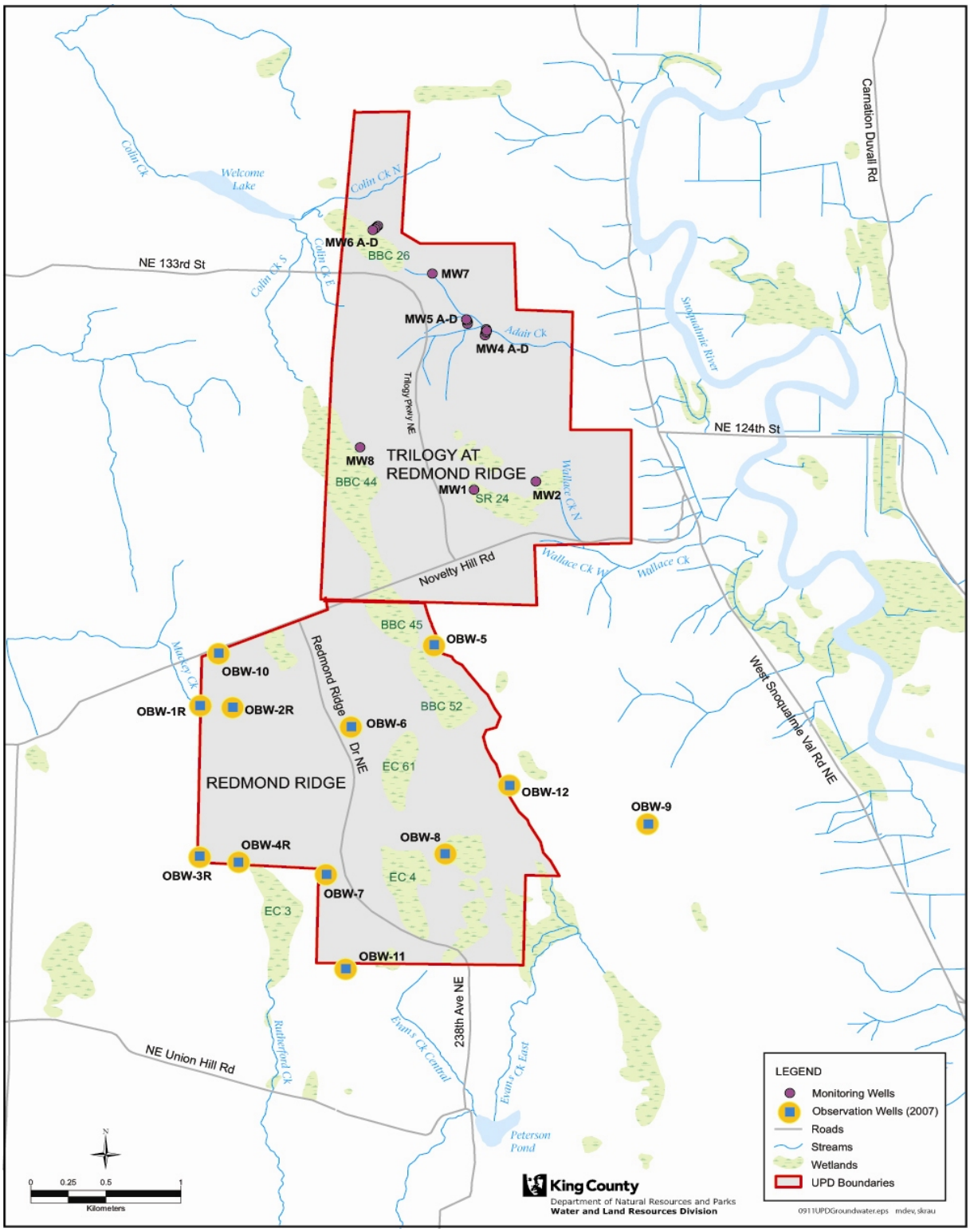

Figure 66. Groundwater monitoring locations.
12 Redmond Ridge observation wells were monitored for water level by AESI in 2007. An additional 7 Trilogy monitoring wells or well transects will be monitored for water level in future years.

Modifications

The Redmond Ridge monitoring plan calls for continuous groundwater level monitoring at 11 observation wells beginning in the first year of construction and concluding 8 years following 75 percent UPD buildout (King County 1999) and no modifications have been made to this monitoring component[82].

Trilogy groundwater level monitoring, which requires year-round monthly water level sampling at eight shallow groundwater monitoring wells (MW) for 3 years following 75 percent buildout (King County 2001), has not been implemented.

Sampling Recommendations – Continue with water level monitoring at the 11 observation wells required by the Redmond Ridge monitoring plan (King County 1999). See Appendix AA for details of the monitoring schedule.

Implement monthly hydrology monitoring at seven of the eight baseline monitoring wells[83] located within the Trilogy UPD in future years.

Procedures

Twenty-three 2- or 6-inch wells have been installed at Redmond Ridge since 1991 within the Vashon advance aquifer, in pre-Vashon age deposits, and in shallow perched groundwater within Vashon lodgement till (Associated Earth Sciences Inc. 2007b). The wells that are currently monitored were installed between 1996 and 1998 except OBW-7R, which was installed in summer 2001 to replace OBW-7. At this time, continuous hourly groundwater level measurements are logged at 12 wells at Redmond Ridge and Redmond Ridge East (Figure 66). At these 12 wells and MW-8 ground water level elevations are also manually recorded once per month.

Results

Redmond Ridge groundwater hydrology results are reported by AESI twice annually in letters directed to Lisa Lee with King County DDES (Associated Earth Sciences Inc. 2007a, b). These letters consistently report that groundwater levels at Redmond Ridge fluctuate between 0.6 to 3.0 m (2 to 10 ft) in response to precipitation with a lag time between peak precipitation and peak groundwater levels of 3 to 7 months. Higher than average groundwater levels were observed in the late 1990s and again from 2004 to 2007, coinciding with years with higher than average rainfall. See the May 22 and October 31, 2007 AESI reports for more details on the groundwater hydrology results (Associated Earth Sciences Inc. 2007a, b).

Threshold Exceedance Criteria and Evaluation

Redmond Ridge groundwater hydrology threshold exceedance criteria are violated if the seasonally adjusted average level of wells OBW-1 through -8 have declines of more than 3 ft (0.91 m) or wells OBW-5 through -8 have declines of more than 11 ft (3.35 m) below baseline

[82] Though not required, a twelfth observation well (OBW-12) and one monitoring well (MW-8) have been monitored for groundwater level at Redmond Ridge. See the twice annual AESI reports for summaries of these data (Associated Earth Sciences Inc. 2007b).

[83] Omit MW-3 since repeated attempts to locate it by both AESI and King County staff have been unsuccessful.

levels for more than two consecutive years when not explainable by precipitation or off-site well pumping (King County 1999). These threshold criteria have not been exceeded to date.

Trilogy exceedance criteria (i.e., deviations beyond the range of allowable variation established during baseline groundwater level monitoring) (King County 2001) cannot be evaluated because sampling has not yet been implemented.

Corrective Actions

No corrective actions are recommended for this component of the monitoring plan.

3.14 Groundwater Quality

Groundwater quality monitoring is required in the Redmond Ridge monitoring plan (King County 1999) to verify that there is no degradation from infiltration facilities of groundwater approaching sensitive receiving bodies (i.e., streams and wetlands) or wells. No groundwater quality monitoring is required in the Trilogy monitoring plan (King County 2001).

Modifications

Quarterly groundwater quality monitoring is required for fecal coliforms and NO_2+NO_3 at six wells in Redmond Ridge (King County 1999) (Figure 66). Sampling was scheduled to be initiated at 75 percent UPD buildout and continue for 3 years (King County 1999)[84]. Groundwater quality monitoring has not yet been implemented.

Sampling Recommendations – Begin sampling of wells OBW-1, -3, -4, -10, and -11 in future years for NO_2+NO_3[85], all of which are in subbasins that have exceeded 75 percent buildout. Well OBW-5 is within Redmond Ridge East and is also included in the sampling design of the Redmond Ridge monitoring plan (King County 1999). However, the design of this well may make sampling impossible[86]. As a result, OBW-5 should be dropped from the groundwater quality monitoring program.

Procedures

Methods for groundwater quality monitoring have not yet been determined. Pumping water from the wells may prove to be difficult because of the distance of the wells from vehicle access, their variable design (both 2- and 6-inch wells), and, in the case of the 6-inch wells, the large volume of water required to purge the well. Methods will be reported when sampling is implemented, but all samples will be processed by the KCEL following approved quality control procedures.

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[84] In contrast to the Redmond Ridge monitoring plan, Section X of the Master Drainage Plan called for initiation at the onset of construction of the infiltration facilities (rather than at 75% buildout) until 3 years after 75% buildout (Hugh G. Goldsmith and Associates 1996).

[85] The Redmond Ridge monitoring plan (King County 1999) calls for analysis of additional groundwater quality parameters (e.g., total phosphorous, soluble reactive phosphorous, total suspended solids, total nitrogen, ammonia, and pH) as needed based on first year results. Fecal coliforms were required in addition to NO_2+NO_3, but may be omitted.

[86] Well OBW-5 has a 2-inch opening, topped with a 1" nipple and opens up to a 6" well. In order to pump water for water quality sampling, it would be necessary to remove this design, which might affect the groundwater hydrology monitoring that has been taking place for many years.

Results

There are no results to report.

Threshold Exceedance Criteria and Evaluation

A repeated trend in water quality degradation away from baseline water quality violates the thresholds established in the Redmond Ridge monitoring plans and could trigger appropriate corrective actions (King County 1999). However, no baseline monitoring took place in the observation wells where groundwater quality monitoring is required. Therefore, comparisons to Department of Health drinking water standards (Washington State Board of Health 2009), which match the EPA drinking water standards (U.S. Environmental Protection Agency 2009), may be more appropriate. Where possible, comparisons could be made to groundwater quality data from area wells from predevelopment conditions.

No data have been collected to evaluate threshold exceedance criteria.

Corrective Actions

No corrective actions are recommended for this component of the monitoring plan.

4.0 STORMWATER FACILITIES PERFORMANCE MONITORING

4.1 Stormwater Facilities Flow Control

The Trilogy and Redmond Ridge monitoring plans call for the assessment of stormwater facility flow control performance with crest-stage gages at all individual facilities to determine if the facilities went into overflow (King County 1999, 2001). Sampling is called for monthly from October to April (Trilogy) or after any 2 year or longer return period storm (King County 1999, 2001). In addition, continuous gages are required at a subset of sites[87] for more comprehensive assessment (King County 1999, 2001). Monitoring is to commence at County acceptance (Redmond Ridge) or 75 percent buildout (Trilogy) and conclude 3 years following 75 percent subbasin buildout.

Modifications

Onset of monitoring has been delayed at most locations, but otherwise there have been no significant modifications to this component of the monitoring program relative to the original requirements described in the monitoring plans (King County 1999, 2001).

Sampling recommendations – There are no recommendations for facility flow control monitoring.

[87] Four Trilogy (SWD1, NWD4, NED9, SED3/4) and three Redmond Ridge (BC-2 No. 1, MC-4 No. 1, ECW-1C No. 1) stormwater facilities call for continuous monitoring in the monitoring plans (King County 1999, 2001).

Procedures

In Redmond Ridge, five crest-stage gages were installed in stormwater facilities in subbasins approaching the 75 percent buildout threshold in 2003. The gages were attached to posts in the stormwater facilities and were surveyed with the facility overflow structures. The gages were observed at monthly intervals initially, and then only after large storms or quarterly. The results of the observations are kept in paper files and an electronic spreadsheet.

Continuous monitoring of the facility ECW1B-1 was accomplished with a water level recorder installed in the control structure. Flow was computed from the design stage-discharge rating and verified with direct measurements of discharge from the stormwater facility where feasible. Data are stored and are available for download in the King County Hydrologic Information Center database (accessible online[88]). Documentation of the data set preparation is stored in hard copy files.

Crest-stage

The five Redmond Ridge facilities monitored for overflow from 2003 through 2007 were BC2-1, ECW3-3, MC1-1, MC2-1, and MC4-1 (Figure 13). They were installed in 2001 and monitored bi-monthly starting January 6, 2003 for two years. In 2005 they were checked after large rain events. None of these stormwater facilities went into overflow during the monitoring period (Table 30).

Table 30. Summary of overflow observations for crest-stage gages at five Redmond Ridge stormwater facilities.

Facility	Observation Summary
BC2-1	Water never reached the bottom of the crest-stage gage
ECW3-3	Pond came within 1 foot of the overflow in December 2003
MC1-1	Water was rarely observed in the pond, no overflows
MC2-1	Water quality facility never went into overflow
MC4-1	Infiltration facility never went into overflow

Continuous

Continuous water level monitoring commenced at stormwater facility ECW1B-1 on November 14, 2003. A recording sensor measured water level in the outlet control structure of the facility. The design discharge from the multiple orifice flow restrictor was verified by measurements of discharge through the overflow basin and at the outlet structure. The relative elevations of the flow restrictors were verified by measuring the distance between them. Discharge was calculated by applying the design stage-discharge rating table to the measured water levels in the control structure.

The retention/detention analysis and design for the facility is included in the Technical Information Report (TIR) for Division 1-C (W & H Pacific 2001). The analysis gives the predevelopment runoff rates for the contributing basin as 2-year 1.07 cfs, 10-year 2.86 cfs, and 100-year 5.97 cfs. After incorporating the various master drainage plan conditions, special requirements, and safety factors, the pond was designed to release half the 2-year rate (0.54 cfs)

[88] http://green.kingcounty.gov/wlr/waterres/hydrology/

for a 2-year 24-hour storm (1.9”); release at the 2-year rate (1.07 cfs) for a 10-year 24-hour storm (2.8”); and release at the 10-year rate (2.87 cfs) for a 100-year 24-hour storm (3.9”).

Figure 67 plots measured daily peak flows with the maximum 24-hour rainfall intensity for each day from rain gage 02V. Target flows and design storm rainfall totals are overlaid. For 57 days, the peak discharge exceeded the 2-year target flow of 0.57 cfs. The rainfall intensity exceeded the 2-year 24-hour storm on three of those days. On two days the peak flow met the 10-year target flow of 1.07 cfs. The flows in excess of the 2-year target all are associated with prolonged rainfall periods. Thirty-four of the 2-year target exceedances occurred during the wet period of December 2005 through early February 2006 when 16 inches of rain fell in 6 weeks. Two of the 2-year rain events resulted in flows less than the 2-year target flow. The safety factor incorporated into the design release flow rate enabled the facility to keep peak flows under the modeled predevelopment 2-year flow for all but two days. The stormwater facility never approached the 100-year release rate and overflow.

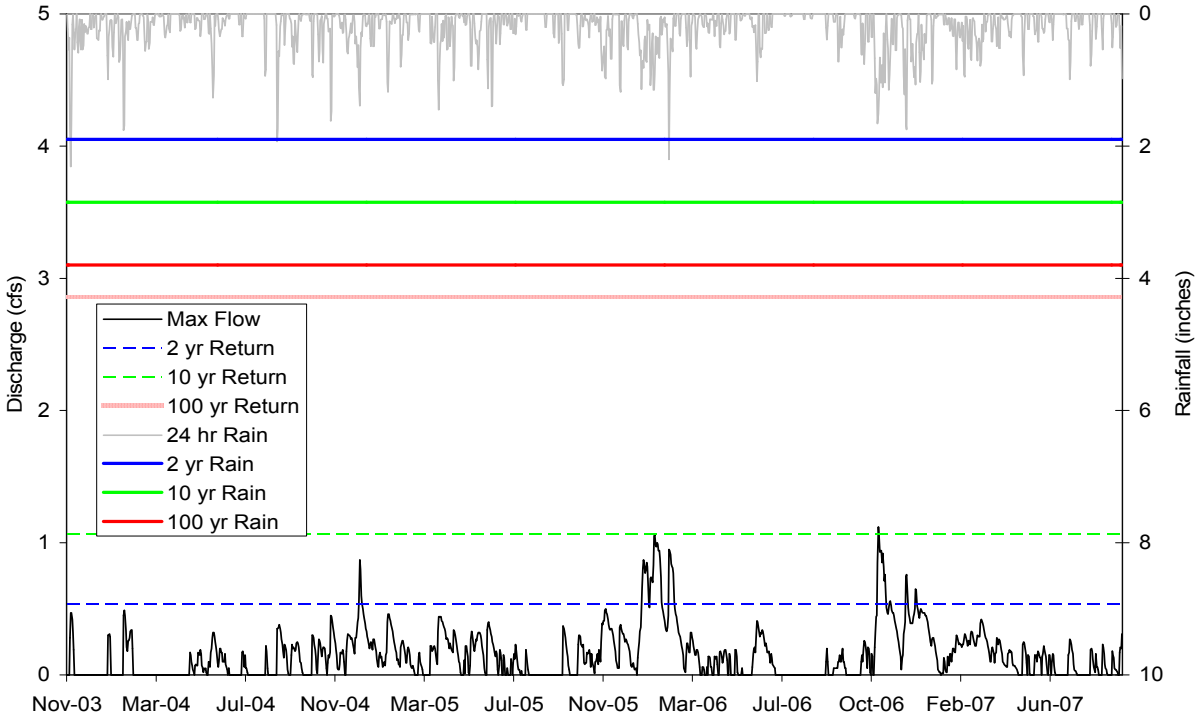

Figure 67. Water surface elevations at stormwater pond ECW1B1 and daily rainfall totals.
Construction began in 1999 and 75% buildout was reached in October 2003 in the Evans Creek West subbasin.

Threshold Exceedance Criteria and Evaluation

The stormwater pond levels were to stay below the overflow level unless the design storm was exceeded. This criterion was never exceeded for the five crest-stage gage monitored locations. The continuous monitoring compared the measured peak flows to targets for design storms. For ECW1B-1, the peak release rates are exceeding the design targets for the 2-year return storm. Peak flow rates are similar to the predevelopment condition.

Corrective Actions

No corrective actions are recommended pending analysis of the 2008-2010 data.

4.2 Stormwater Facilities Water Quality Performance

The Trilogy and Redmond Ridge monitoring plans call for the assessment of stormwater facility water quality performance at three Trilogy and two Redmond Ridge locations[89]. This monitoring will commence during the 2008 water year and will be summarized in the 2008-2010 monitoring report.

[89] The two Redmond Ridge facilities will be ECW1B-1 & ECW3-1 and the three Trilogy facilities will be NED9, NWD4, SWD3.

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6.0 APPENDICES

Appendix A. Names, numbers, and drainage basin for streams draining the UPDs

Table A-1. UPD Stream names, drainage basins, and stream numbers.
UPD related monitoring activities have been conducted on the ten creeks shown below. The 'alternative name' may have been used previously in the master drainage plans, earlier reports, or the monitoring plans.

UPD	Stream Name	Alternative Name	Drains Subbasin	Stream Number[90]
Trilogy	Adair Creek		NED	07-0275
	Colin Creek North		NWD	08-0133
	Colin Creek South		SWD	08-0132
	Colin Creek East		NWD	08-0134
	Wallace Creek North	Unnamed North	SED	N/A
	Wallace Creek	Unnamed	SED	07-0276
	Wallace Creek West	Unnamed West	SED	07-0277
Redmond Ridge	Mackey Creek		MC	08-0117A
	Rutherford Creek	Evans Creek West	ECW	08-0110
	Evans Creek Central	Evans Middle Fork	ECC	08-0113
	Evans Creek East		ECE	N/A

[90] The Washington Department of Fisheries created a catalog of Washington's streams in the 1970s assigning stream numbers as a method of identifying individual streams. The first two digits represent the Water Resources Inventory Area (WRIA) followed by four numbers that were assigned consecutively from north to south (Williams et al. 1975).

Appendix B. Macroinvertebrate sampling schedule

Table B-1. Sampling schedule through 2007 for benthic macroinvertebrate monitoring.
1991 sampling is omitted because organisms were only identified to family level. 1997 and 2005 sampling is omitted because collections were conducted in the fall rather than between late May and early June. 2007 sampling events are bolded. Richard Lowe of King County DDES estimated 75% buildout within each subbasin (Lowe 2005, 2008). Construction periods are estimated from development phasing maps (KPFF Consulting Engineers 2004, Otak Incorporated 2006) and aerial photographs (1998, 2000, 2002, 2005, 2007, and 2009). Post-development is defined as after 75% subbasin buildout.

	Redmond Ridge			Trilogy			
	Ruther-ford	**Evans Central**	**Evans East**	**Adair (NED)**	**Wallace (SED)**	**Colin South (SWD)**	**Colin North (NWD)**
Construction Start	**1999**	**2000**	**2003**	**2002**	**2001**	**2001**	**2003**
75% buildout	**Oct '03**	**Oct '05**	**N/A[a]**	**Nov '06**	**Sept '05**	**Aug '02**	**Oct '06**
Preconstruction		1999	1999 2000 2001	1999 2000 2001	1999 2000	1999	1999 2000 2001
During construction	1999 2000 2001	2000 2001	2006	2006	2001	2000 2001	2006
Post-development	2006	2006		**2007**	2006 **2007[b]**	2006	

[a] The Evans Creek East subbasin has very little development in Redmond Ridge or Trilogy (limited to the eastern portion of Division 12 in 2003) (Figure 3). Redmond Ridge East construction began in 2007, which does drain to the Evans Creek East subbasin.
[b] Wallace Creek West was mistakenly sampled in 2007 instead of Colin North.

Appendix C. 2007 Macroinvertebrate taxonomic data

Table C-1. Macroinvertebrate taxonomic data (2007).

Organisms were collected and preserved on June 5, 2007 under Scientific Collection Permit #07-229 in King County, Washington.

		Site	**Adair Ck**	**Unnamed Ck**
		WRIA #	07-0275	07-0276
		Northing (State Plane)	262,790	258,305
		Easting (State Plane)	1,349,424	1,349,176
		Sample date	6/5/2007	6/5/2007
Order	**Family**	**Taxon**	**Count**	**Count**
Non-insect taxa		Turbellaria	1	0
		Nematoda	3	6
		Oligochaeta	2	2
	Pisidiidae	Pisidiidae	1	18
	Acari	Acari	1	9
Ephemeroptera	Baetidae	*Baetis tricaudatus*	9	22
		Diphetor hageni	4	0
	Ephemerellidae	*Drunella doddsi*	0	2
	Heptageniidae	*Cinygma*	4	26
		Heptageniidae - damaged/early instar	4	0
		Ironodes	4	0
	Leptophlebiidae	*Paraleptophlebia vaciva*	5	5
		Paraleptophlebia - early instar	0	6
Plecoptera	Chloroperlidae	Chloroperlidae - early instar	5	4
		Suwallia	1	0
		Sweltsa	13	42
	Leuctridae	*Despaxia augusta*	3	0
		Leuctridae - early instar	1	1
		Moselia infuscata	0	1
	Nemouridae	*Malenka*	33	22
		Zapada cinctipes	9	18
		Zapada columbiana	0	11
	Perlidae	*Calineuria californica*	2	1
		Perlidae - early instar	3	0
	Perlodidae	Perlodidae - early instar	2	1

Table C-1. (cont'd)

		Site	Adair Ck	Unnamed Ck
Order	**Family**	**Taxon**	**Count**	**Count**
Trichoptera	Glossosomatidae	*Glossosoma*	22	0
	Hydropsychidae	*Parapsyche almota*	24	6
		Parapsyche elsis	0	12
	Lepidostomatidae	*Lepidostoma*	3	6
	Limnephilidae	*Cryptochia*	1	0
		Ecclisomyia	0	4
		Limnephilidae - early instar or pupa	4	2
		Pseudostenophylax	1	0
	Philopotamidae	*Wormaldia*	48	27
	Rhyacophilidae	*Rhyacophila - early instar or pupa*	1	3
		Rhyacophila Angelita Gr.	2	0
		Rhyacophila Betteni Gr.	2	1
		Rhyacophila blarina	1	0
		Rhyacophila Brunnea Gr.	1	0
		Rhyacophila narvae	0	2
	Uenoidae	*Neophylax splendens*	3	2
Coleoptera	Elmidae	*Heterlimnius*	2	0
		Lara avara	2	0
		Optioservus	4	0
		Zaitzevia	30	0
Diptera	Ceratopogonidae	Ceratopogoninae	2	2
		Forcipomyiinae	1	0
	Dixidae	*Dixa*	3	0
	Empididae	Empididae - early instar or pupa	0	1
	Simuliidae	*Simulium*	2	47
	Tipulidae	*Austrolimnophilia*	0	1
		Hexatoma	6	11
		Limnophila	0	1
		Pilaria	0	1
	Thaumaliidae	*Thaumalea*	0	1
	Chironomidae	Chironomidae	88	55
		Totals	363	382

Appendix D. Levels of biological condition for BIBI scores

Table D-1. BIBI biological condition categories.
Ten individual BIBI metric scores are combined to give a total BIBI score ranging from 10-50, which can be classified into five levels of biological condition. Modified from Karr et al. (1986) by Morley (2000).

Biological Condition	BIBI Range	Description
Excellent	46-50	Comparable to least disturbed reference condition; overall high taxa diversity, particularly of mayflies, stoneflies, caddis flies, long-lived, clinger, and intolerant taxa. Relative abundance of predators high.
Good	38-44	Slightly divergent from least disturbed condition; absence of some long-lived and intolerant taxa; slight decline in richness of mayflies, stoneflies, and caddis flies; proportion of tolerant taxa increases
Fair	28-36	Total taxa richness reduced – particularly intolerant, long-lived, stonefly, and clinger taxa; relative abundance of predators declines; proportion of tolerant taxa continues to increase
Poor	18-26	Overall taxa diversity depressed; proportion of predators greatly reduced as is long-lived taxa richness; few stoneflies or intolerant taxa present; dominance by three most abundant taxa often very high
Very Poor	10-16	Overall taxa diversity very low and dominated by a few highly tolerant taxa; mayfly, stonefly, caddis fly, clinger, long-lived, and intolerant taxa largely absent; relative abundance of predators very low.

Appendix E. Amphibian breeding monitoring schedule

Table E-1. Amphibian breeding monitoring schedule through 2007.
2007 sampling is highlighted in bold. 75 percent buildout dates were estimated by Richard Lowe (2005, 2008). Construction dates were estimated based on clearing start dates[91] from development maps (KPFF Consulting Engineers 2004, Otak Incorporated 2006) and aerial images (1998, 2000, 2002, 2005, 2007). Post-development is defined as following 75 percent buildout.

	Redmond Ridge		Trilogy		
	BBC-52	**BBC-45 (u/s & d/s)**	**BBC-44**	**BBC-26**	**SR-24C**
Construction start	**2001**	**2001**	**2001**	**2003**	**2001**
75% buildout	**Not projected**	**Not projected**	**Aug '02**	**Oct '06**	**Sept '05**
Preconstruction	2000 2001	2000 2001	2001	2002 2003	2000 2001
During construction	2002 2003 2004 2005 2006 **2007**	2002 2003 2004 2005 2006 **2007**	2002	2004 2005 2006	2002 2003 2004 2005
Post-development			2003 2004 2005 2006 **2007**	**2007**	2006 **2007**

[91] Clearing took place during the dry season between April 1st and September 30th each year.

Appendix F. 2007 Amphibian breeding survey data

Table F-1. Raw data for 2007 amphibian breeding surveys.

Includes water quality and egg mass mortality.

Wetland	Date	Crew	Time (min)	Species	Tag	% Egg Mass Mortality 0	1-5	6-25	26-50	51-75	76-95	96-100	part hatch	Temp °C	pH	DO %	DO mg/L	Cond. µS/cm	Sp Cond µS/cm	Gage ft	Weather	Comments
BBC26	3/6	JOW, RT	285	NWSA		555	41	6	4	2	2			7.4	4.9	77.1	9.23	49.7	74.5		mostly sunny & warm	
BBC26	3/6	JOW, RT	285	RLFR		3	3							7.4	4.9	77.1	9.23	49.7	74.5			
BBC26	4/10	JOW, CH	249	NWSA	No	201	43	3	4	4	0	1	5	12.4	5.3	84.5	9.07	54.4	71.6		overcast, 50s, partial sun breaks	
BBC26	4/10	JOW, CH	249	NWSA	Yes	200	51	2	4	4	1	0	2	12.4	5.3	84.5	9.07	54.4	71.6			lots of geese in the area
BBC26	4/10	JOW, CH	249	PATR	No	5	0	0	0	0	0	1		12.4	5.3	84.5	9.07	54.4	71.6			
BBC44	3/15	JOW, BK	210	NWSA		167	44	3	1					7.3	4.8	57.6	6.94	33.8	51.1		overcast, light rain last hour of survey	PATR calling , 1 dead, decomposing adult NWSA
BBC44	3/15	JOW, BK	210	PATR		0	0	0	0	0				7.3	4.8	57.6	6.94	33.8	51.1			
BBC44	4/19	JOW, CH	117	NWSA	Yes	27	35	7	1	0	0	0	7	9.8	5	59.5	6.74	33.3	46.8		overcast, cool, light rain, periods of sun	1 dead PATR no deformities; hummingbird, Canada goose
BBC44	4/19	JOW, CH	117	NWSA	No	34	37	8	1	0	0	0	4	9.8	5	59.5	6.74	33.3	46.8			
BBC45 d/s	3/15	JOW	26	NWSA		2	3	3	9	9	2	1		6	4.6	45.8	5.78	10.5	16.4	2.24	overcast, cool	
BBC45 d/s	3/16	JOW, JF	18	NWSA		6	12	11	7	9	3			8.5	4.4	61.2	7.17	11.6	17	2.24	partly cloudy, sun breaks	found an empty gallon jug of gear lubricant
BBC45 d/s	4/12	JOW, CH	21	NWSA	No	0	1	1	2	3	0	1	4	11.8	4.7	42.9	4.63	12.8	17.1	2.18	overcast, no sun	
BBC45 d/s	4/12	JOW, CH	21	NWSA	Yes	0	3	1	6	10	7	16		11.8	4.7	42.9	4.63	12.8	17.1	2.18		
BBC45 u/s	3/13	JOW, JV	25	NWSA		7	4	2						9	4.4	47.5	5.48	10.4	15.9		cloudy, partial sun breaks, 40s F	
BBC45 u/s	3/13	JOW, JV	25	PATR		4	0	1						9	4.4	47.5	5.48	10.4	15.9			
BBC45 u/s	3/13	JOW, JV	25	RLFR		0	3							9	4.4	47.5	5.48	10.4	15.9			
BBC45 u/s	4/12	JOW, CH	13	NWSA	No	0	1	1	0	1	0	0		11		24	2.71	15.1	20.7		overcast, no sun	
BBC45 u/s	4/12	JOW, CH	13	NWSA	Yes	1	4	0	1	0	0	0		11		24	2.71	15.1	20.7			
BBC52	3/12	JOW, KC	95	NWSA		16	18	0						10.1	5	64.7	7.26	12.5	17.5		overcast	1 NWSA egg mass above water surface; Lots of PATR calling
BBC52	3/12	JOW, KC	95	PATR		56	12	2	2	2	1	5		10.1	5	64.7	7.26	12.5	17.5			
BBC52	3/12	JOW, KC	95	RLFR		1	13	6	1					10.1	5	64.7	7.26	12.5	17.5			
BBC52	3/13	JOW, JV	95	NWSA		5	9	1						9.1	4.6	48.3	5.56	12.6	18.1		overcast with occasional sun breaks, windy	a few PATR calling; 1 dead adult RLFR
BBC52	3/13	JOW, JV	95	PATR		53	14	5	0	1	1	4		9.1	4.6	48.3	5.56	12.6	18.1			
BBC52	3/13	JOW, JV	95	RLFR		2	18	2	1					9.1	4.6	48.3	5.56	12.6	18.1			
BBC52	3/14	JOW, CH	237	NWSA		29	17	6	2	1	4	2		8	4.6	53.3	6.31	12.4	18.4	3.07	cloudy with sun breaks	1 deer drinking from wetland
BBC52	3/14	JOW, CH	237	PATR		223	29	25	15	8	7	47		8	4.6	53.3	6.31	12.4	18.4	3.07		
BBC52	3/14	JOW, CH	237	RLFR		1	2	1	0	0	0	1		8	4.6	53.3	6.31	12.4	18.4	3.07		
BBC52	4/12	JOW, CH	147	NWSA	No	9	28	9	2	0	0	3	1	12	4.7	46.2	4.98	13.6	18.1	2.92	overcast, no sun	Urine smell; 2 dead adult PATR - no deformities, one very decomposed; a few PATR calling
BBC52	4/12	JOW, CH	147	NWSA	Yes	8	18	5	1	0	0	2		12	4.7	46.2	4.98	13.6	18.1	2.92		
BBC52	4/12	JOW, CH	147	PATR	No	17	3	0	0	1	0	0	2	12	4.7	46.2	4.98	13.6	18.1	2.92		
BBC52	4/12	JOW, CH	147	PATR	Yes	4	0	0	0	0	0	0	2	12	4.7	46.2	4.98	13.6	18.1	2.92		
SR24C	3/16	JOW, JF	184	NWSA		121	30	8	5	1	0	3	5	6.5	5	52.2	6.43	22.1	34.1			3 adult bullfrogs submerged on wetland bottom
SR24C	4/11	JOW, KC	224	NWSA	No	50	15	2	1	0	0	0	15	7.5	4.8	58.8	7.06	22.8	34.2		overcast, partial sun clearings	Bullfrogs jumping and calling
SR24C	4/11	JOW, KC	224	NWSA	Yes	63	19	3	3	0	0	2	17	7.5	4.8	58.8	7.06	22.8	34.2			
SR24C	4/11	JOW, KC	224	PATR	No	6	0	0	0	0	0	0		7.5	4.8	58.8	7.06	22.8	34.2			

JOW = Jo Wilhelm, BK = Bob Keating; RT = Ray Timm; CH = Caitlin Holliday; JF = Jonathon Frodge; JV = Jen Vanderhoof; KC = Kyle Comanor; NWSA = Northwestern salamander; RLFR = Northern red-legged frog; PATR = Pacific treefrog; Tag refers to whether an egg mass found in the second survey was previously marked during the first survey

Appendix G. Fish sampling schedule

Table G-1. Schedule through 2007 for fish sampling for four creeks draining the UPDs.
2007 sampling is highlighted in bold. 75% buildout dates were estimated by Richard Lowe (2005, 2008). Construction dates were estimated based on clearing start dates[92] from development maps (KPFF Consulting Engineers 2004, Otak Incorporated 2006) and aerial images (1998, 2000, 2002, 2005, 2007). Post-development is defined as following 75% buildout.

	Redmond Ridge	**Trilogy**		
	Evans East	**Adair**	**Wallace**	**Colin South**
Construction Start	**2003**	**2002**	**2001**	**2001**
75% buildout	**N/A[a]**	**Nov '06**	**Sept '05**	**Aug '02**
Preconstruction	1991 2000	1991 2000	1991 2000	1991 2000
During construction	2006	2006		
Post-development		**2007**	2006 – DNS[b]	2006

[a] The Evans Creek East subbasin has very little development in Redmond Ridge or Trilogy (limited to the eastern portion of Division 12 in 2003) (Figure 3). Redmond Ridge East construction began in 2007, which does drain to the Evans Creek East subbasin.
[b] DNS = did not sample because of lack of landowner permission

[92] Clearing took place during the dry season between April 1 and September 30 each year.

Appendix H. Fish abundance estimates

Abundance estimates using the methods outlined in Lockwood and Schneider (2000) indicate that coho abundance has increased including a 109% increase between 2000 and 2006 and a 4% increase between 2006 and 2007 (Figure H-1). Cutthroat trout abundance fluctuated between years declining approximately 92% between 2000 and 2006 before doubling between 2006 and 2007. Riffle sculpin were not observed in 2000, then dropped almost 74% in abundance between 2006 and 2007. Rainbow trout were observed for the first time in 2007.

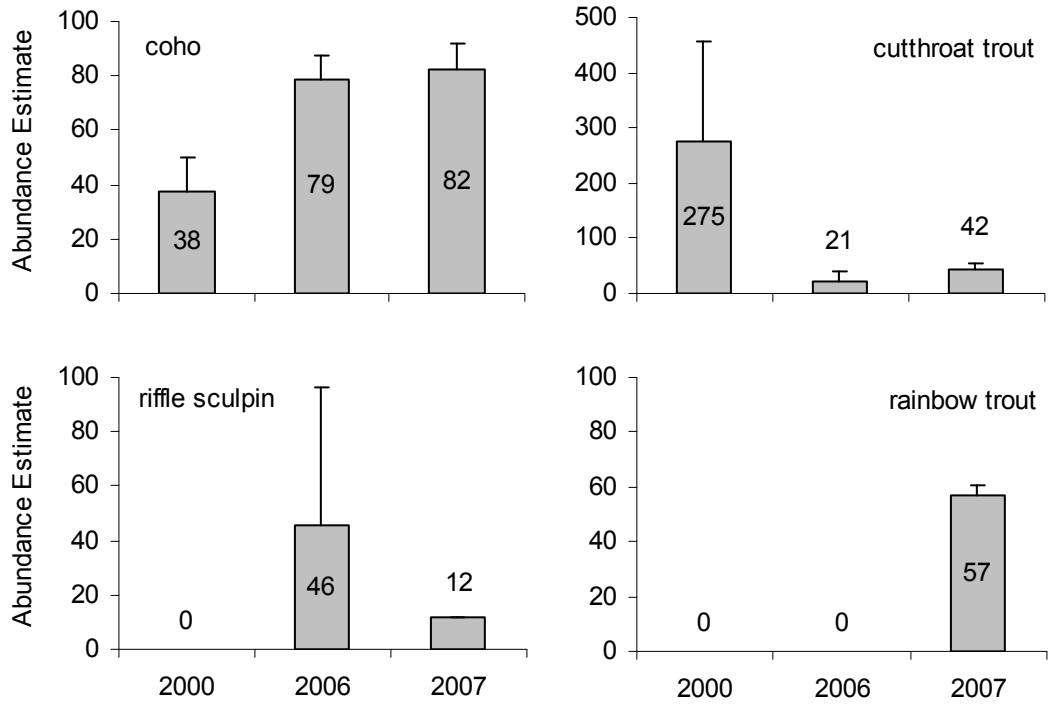

Figure H-1. Adair Creek fish abundance estimates.
Abundance estimates within each sample reach were calculated from three electrofishing passes for each species present using the methods outlined in Lockwood and Schneider (2000). Error bars represent 95% confidence intervals. 1991 data are not compared for abundance estimates because results were from a different time of year and for different sample reach lengths.

There is extensive variability in population estimates based on the method used to calculate them (Figure H-2). For example, the estimates of population abundance for Adair Creek cutthroat trout in 2000 ranged from 275 $\pm$ 183 (95% confidence interval) to 404 $\pm$ 271.

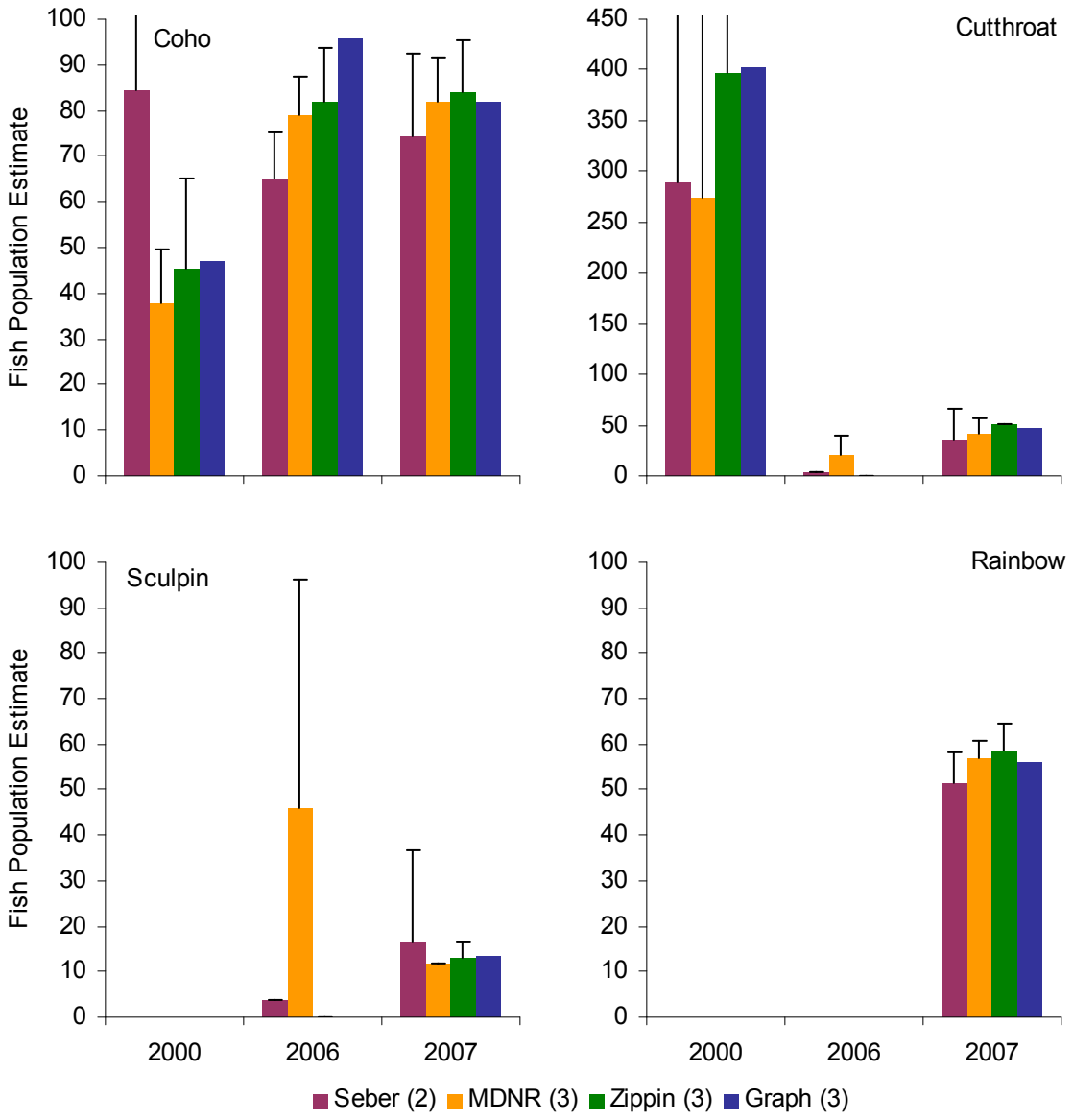

Figure H-2. Comparison of fish population estimates calculated by different methods.
Error bars represent the upper 95% confidence interval. The number in parentheses in the legend represents the number of passes the estimate is calculated from. If the fish population was not being depleted, no estimate could be made using most methods (e.g., cutthroat and sculpin in 2006). Estimation formulas are described in Seber and Cren (1967), Lockwood and Schneider (2000), and Zippin (1958).

Appendix I. 2007 Adair Creek UPD fish data

Site information
Adair Creek UPD Fish Sampling
June 19, 2007 Weather sunny and warm
Jo Wilhelm, Josh Latterell, Caitlin Holliday
Water Quality Variables (from YSI sonde):
95.6% D.O., 10.31 mg/L D.O., 70.3 µS, 93.7 µS, 11.9ºC
92 m reach length starts ~60 m upstream of West Snoqualmie Valley Road

Table I-1. Electrofishing pass details (2007).

	Pass 1	Pass 2	Pass 3
Start time	11:10	14:32	16:11
End time	12:46	15:42	16:47
Total Time (hr:min)	1:36	1:10	0:36
Shocker setting	F4 300/F4 400	F4 400	F4 400
# of Pacific Giant Salamanders	14	9	4
Crayfish	0	1	1
Electro-shocker	Josh	Caitlin	Josh
Small nets	Jo	Jo	Jo
Large nets	Caitlin	Josh	Caitlin

Table I-2. Raw electrofishing data for Adair Creek (2007).
Fish collected during 2007 Adair Creek fish sampling on 6/17/09. Lengths listed in red are fish mortalities; those in italics were noted as 'fry' in the field notes (distinguishing between cutthroat and rainbow was less certain).

Pass	Species	Total Length (mm)
1	Coho	68 65 68 72 56 68 63 55 56 52 55 68 65 64 60 61 65 73 66 63 73 58
		48 57 57 65 67 64 68 55 60 70 54 59 63 68 65 75 65 66 65 73 51 45
	Cutthroat	103 *40 40 38 50 41 34 36 38 44 38 47 50 46 37 34*
	Rainbow	103 110 *38 42 42 42 41 37 43 37 36 44 40 42 42 40 37 41 40 40 41 40*
		40 43 45 44 42 42 39 40 41 45 39 40 40 46 37 47
	Sculpin	73 84 75 84 83 86 74
2	Coho	49 62 60 65 71 59 53 47 48 65 67 65 50 35 35 59 35 34
	Cutthroat	*39 37 43 38 45 41 44 38 34 38 39 43 40 41 44 44 39 41 36*
	Rainbow	*38 39 43 40 41 44 44 39 41 36*
	Sculpin	84 98 81 85
3	Coho	52 62 66 46 80 53 64 65 62 63 80 60
	Cutthroat	*37 42 44 41 40 42 46 40*
	Rainbow	*42 37 38 41 40 39 40*
	Sculpin	88

Appendix J. Wetland hydrology sampling schedule

Table J-1. Schedule through 2007 for hydrology sampling at 12 UPD wetlands.
2007 sampling is highlighted in bold. Post-development 75% buildout dates were estimated by Richard Lowe (2005, 2008). Construction dates were estimated based on clearing start dates[93] from development maps (KPFF Consulting Engineers 2004, Otak Incorporated 2006) and aerial images (1998, 2000, 2002, 2005, and 2007). Hydrology monitoring continues until all other subbasin monitoring is completed.

	Redmond Ridge					Trilogy			
Subbasin	**Mackey**	**Rutherford**	**Evans Central**	**BBC**		**Wallace**		**Colin South**	**Colin North**
Gaging Sites	**BBC-UN1**	**EC-3**	**EC-61, EC-4**	**BBC-45a**	**BBC-52, BBC-45**	**SR-24A & C**	**SR-24B**	**BBC-44**	**BBC-26**
Gage Type	**Continuous**	**Continuous**	**Continuous**	**S/C**	**Continuous**	**S/C**	**Continuous**	**Continuous**	**S/C**
Construction Start	**1998**	**1999**	**2000**	**2001**		**2001**		**2001**	**2003**
75% buildout	**Sept '01**	**Oct '03**	**Oct '05**	**TBD**		**Sept '05**		**Aug '02**	**Oct '06**
Preconstruction	1987-1991	1987-1991	1987-1991	1990-1993 2000	1987-1991 2000	1990-1994	2000		1990-1994 2000 2001 2002
During construction		2002 2003	2002 2003 2004 2005	2001 2002 2003 2004 2005 2006 **2007**	2001 2002 2003 2004 2005 2006 **2007**	2002 2003 2004	2001 2002 2003 2004	2001 2002	2003 2004 2005 2006
Post-development	2005 2006 **2007**	2004 2005 2006 **2007**	2006 **2007**			2005 2006 **2007**	2005 2006 **2007**	2003 2004 2005 2006 **2007**	**2007**

[93] Clearing took place during the dry season between April 1 and September 30 each year.

Appendix K. Stream hydrology sampling schedule

Table K-1. Schedule through 2007 for hydrology sampling at 7 streams and 2 bypasses.
2007 sampling is highlighted in bold. Post-development 75% buildout dates were estimated by Richard Lowe (2005, 2008). Construction dates were estimated based on clearing start dates[94] from development maps (KPFF Consulting Engineers 2004, Otak Incorporated 2006) and aerial images (1998, 2000, 2002, 2005, and 2007).

	Redmond Ridge				**Trilogy**				
Subbasin	**Rutherford**	**Evans Central**	**Adair**			**Wallace**		**Colin South**	**Colin North**
Gage Sites	**18F**	**18B**	**53A**	**53D (Bypass)**	**53B**	**53C**	**53F (Bypass)**	**02D**	**02C**
Construction Start	**1999**	**2000**	**2002**			**2001**		**2001**	**2003**
75% buildout	**Oct '03**	**Oct '05**	**Nov '06**			**Sept '05**		**Aug '02**	**Oct '06**
Preconstruction		1999	1998 1999 2000 2001		1998 1999 2000	1990-1994			
During construction	2001 2002 2003	2000 2001 2002 2003 2004 2005	2002 2003 2004 2005 2006	2003 2004 2005 2006	2001 2002 2003 2004 2005	2002 2003 2004 2005	2005	2001 2002	2001 2002 2003 2004 2005 2006
Post-development	2004 2005 2006 **2007**	2006 **2007**	**2007**	**2007**	2006 **2007**	2006 **2007**	2006 **2007**	2003 2004 2005 2006 **2007**	**2007**

[94] Clearing took place during the dry season between April 1 and September 30 each year.

Appendix L. Data collected from 2002 and 2005 stream channel characterization surveys

Table L-1. Data collected during 2002 stream channel characterization surveys.

See 1998-2001 annual reports for description of methods and categories (Comings et al. 2000, Comings et al. 2001a, b).

					Bank Stability					Pools							
Creek	Reach	Begin (m)	End (m)	Defined Banks	Henshaw	Henshaw Local	Galli	Bed Material	LWD	Montg	Pools	Riffle Distance	Bio-fouling (%)	Embedded-ness (Galli, %)	Cemen-tation	D50 (mm)	<4mm (%)
Adair	1	0	101	Y	Mod. Unstable	Mod. Unstable	2	G	19	8	2	11	2	26	3	16	9.7
	2	101	201	Y	Slight Unstable	Slight Unstable	3	G	17	8	2	137	0	39	1	32	12.1
	3	201	304	Y	Slight Unstable	Stable	3	G	22	7	0	286	0	0	2	22	15.4
	4	304	435	Y	Stable	Stable	4	G	29	4	2		0	0	1	22	12.1
	5	435	537	Y	Stable	Slight Unstable	4	G	20	2	5	537	0	33	3	45	13.6
	6	537	639	Y	Stable	Mod. Unstable	4	G	22	6	1	605	0	13	1	45	5.8
	7	639	785	Y	Mod. Unstable	Slight Unstable	3	G	9	3	2		0	35	1	45	16.5
	8	785											0				
Colin East	1	0	101	Y	Stable		4	M	11	2	1						
	2	101	201	Y	Stable	Stable	4	G	9	6	0	370	0	10	3	16	7.5
	3	201	249	Y	Stable	Stable	4	G	4	2	0	725	0	6	2	22	4.6
Colin North	1	0	101	N	Unstable		1	M	13	0	2						
	2	101	201	N					2	1	1	590		36		11	14.6
	3																
	4	0	101	Y	Stable	Stable	4	G/M	6	9	0	45	0	19	3	16	8.2
	5	101	201	Y	Stable	Slight Unstable	4	G	9	2	7	316		28	4	11	3.8
	6	201	245	Y	Stable		4	G	0	1	0	698		18	2	16	4.8
Colin South	1	0	101	Y	Stable	Stable	4	G	9	6	1	60	30	46	3	16	22.4
	2	101	201	Y	Stable	Slight Unstable	4	G	4	6	2	357	2	4	4	22	5.4
	3	201	309	Y	Stable	Stable	4	G	14	2	2	727	0	7	3	16	9.4
	4	309	410	Y	Stable	Stable	4	G	25	3	3	128	10	20	2	16	6.6
	5	410	511	Y	Stable	Stable	3	G	12	2	1	1411	0	32	2	32	15.8
	6	511	611	Y	Slight Unstable	Mod. Unstable	3	G	10	4	0	1730	0	6	2	32	3.8
	7	611	712	Y	Stable	Stable	4	G	14	7	1	2039	0	9	3	16	17.1
	8	712	812	Y	Slight Unstable	Unstable	2	G	11	3	0	2621	1	3	3	22	0.9
	9	812	913	Y	Slight Unstable	Slight Unstable	3	G	12	2	0	2738	0	4	2	22	11.4
	10	913	1013	Y	Stable	Slight Unstable	4	G	24	7	0	3114	0	2	1	22	1.9
	11	1013	1114	Y	Stable	Stable	4	G	14	3	0	3532	0	27	1	22	16.3
	12	1114	1215	Y	Stable	Unstable	4	G	5	0	0	3974		3	2	22	1.9
	13	1215	1364	Y	Stable	Slight Unstable	4	G	13	3	1	4238		8	2	22	5.7

Table L-1 (cont'd).

Creek	Reach	Begin (m)	End (m)	Defined Banks	Bank Stability			Bed Material	LWD	Pools		Riffle Distance	Bio-fouling (%)	Embedded-ness (Galli, %)	Cemen-tation	D50 (mm)	<4mm (%)
					Henshaw	Henshaw Local	Galli			Montg	Pools						
Evans East	1	0	102	Y	Stable	Stable	4	G	12	5	5	48	0	0	3	22	8.8
	2	102	201	Y	Stable	Stable	4	G	11	4	7	186	0	0	4	22	6.7
	3	201	302	Y	Stable	Stable	4	G	31	7	2	237	0	0	4	16	
	4	302	386	Y	Stable	Stable	4	G	6	7	1	363	0	0	4	8	19.0
	5	386	487	Y	Slight Unstable	Stable	3	G	13	4	5	457	0		1	4	41.0
	6	487	581			Stable			5	5	1	542	0	0	2	11	23.3
	7	581	687			Slight Unstable			16	4	4	673	0	0	3	8	24.0
	8	687	784			Slight Unstable			8	7	3	760	0	0	2	22	10.8
	9	784	824			Slight Unstable			5	0	2	797	0	0	3	11	18.7
Evans Central	1	0	101	N				V	16	1	1	no riffles					
	2	101	201	N				V	8	3	0	no riffles					
	3	201	302	N				V	12	2	0	no riffles					
	4	302	402	N				V	11	0	0	no riffles					
	5	402	503	N				V	5	0	0	no riffles					
	6	503	604						11	0	1	no riffles					
	7	604	761	Y				M	24	0	5	no riffles					
	8	761															
Wallace	1	0	101	Y	Stable		4	M	4	1	6						
	2	101	201	Y	Stable	Stable	4	G	7	9	1	359	0	2	4	16	8.3
	3	201	302	Y	Stable	Stable	4	G	5	1	0	936	0	9	3	16	16.0
	4	302	402	Y	Stable	Stable	4	G	42	1	0	1112	0	3	3	32	4.5
	5	402	503	Y	Stable	Stable	4	G	27	1	0	1616	0	3	4	22	6.7
	6	503	604	Y	Stable	Stable	4	G	38	3	0	1945	0	23	3	22	9.4
	7	604	704	Y	Stable	Slight Unstable	4	G	27	5	1	2095	0	33	3	22	16.7
	8	704	805	Y	Slight Unstable	Mod. Unstable	3	G	22	1	6	2539	0	10	4	11	8.7
	9	805	905	Y	Slight Unstable	Slight Unstable	3	G	37	3	1	2940	0	1	4	32	6.7
	10	905	1006	Y	Stable	Stable	4	G	42	4	3	3249	0	14	3	16	8.7
	11	1006	1106	Y	Stable	Stable	4	G	19	2	0	3381	0	9	4	32	11.5
	12	1106	1207	Y	Stable	Slight Unstable	4	G	6	1	0	3726	0	14	3	32	16.7
	13	1207	1308	Y	Stable	Slight Unstable	4	G	9	1	0	4160	0	14	2	22	13.3
	14	1308	1398	Y	Stable	Slight Unstable	4	G	1	0	0	4512	0	0	3	22	8.3

Table L-1 (cont'd).

Creek	Reach	Begin (m)	End (m)	Defined Banks	Bank Stability Henshaw	Bank Stability Henshaw Local	Bank Stability Galli	Bed Material	LWD	Pools Montg	Pools Pools	Riffle Distance	Bio-fouling (%)	Embedded-ness (Galli, %)	Cemen-tation	D50 (mm)	<4mm (%)
Colin South	1	0	100	Y		Stable	4	GM	20	3	3	47	0	0		16	5.3
	2	100	200	Y		Stable	4	GM	8	2	2	124	0	0		16	8.7
	3	200	300	Y		Stable	4	GM	21	2	2	210	0	0		16	1.8
	4	300	400	Y		Stable	4	GM	19	3	2	317	0	0		11	6.8
	5	400	500	Y		Stable	4	G	14	0	0	418	0	0		16	4.0
	6	500	600	Y		Stable	4	G	12	3	2	518	0	0		22	5.7
	7	600	700	Y		Stable	4	G	19	7	4	637	0	0		22	0.0
	8	700	800	Y		Stable	4	G	16	1	0	730	0	0	3	16	0.9
	9	800	900	Y		Stable	4	G	21	3	2	824	0	0	3	22	2.0
	10	900	1000	Y		Stable	4	G	29	11	3	918	0	0	3	11	3.8
	11	1000	1100	Y		Stable	4	G	23	7	1	1034	0	0	3	16	0.9
	12	1100	1200	Y		Stable	4	G	7	5	4	1146	0	0	3	11	3.7
	13	1200	1300	Y		Stable	4	G	8	7	3	1280	0	0	3	16	1.8
	14	1300	1400	Y		Stable	4	G	10	6	4	1365	0	0	3	16	2.0
Evans Central	1	0	100	N		Stable	4	M	11	2	1	no riffles					
	2	100	193	N		Stable	4	M	9	3	0	no riffles					
	3	230	300	N		Stable	4	M	5	1	0	no riffles					
	4	300	400	N		Stable	4	M/V	10	1	1	no riffles					
	5	400	500	N		Stable	4	M	3	1	0	no riffles					
	6	500	600	N		Stable	4	M	7	4	2	no riffles					
	7	600	700	N		Stable	4	M	20	9	6	no riffles					
	8	700	800	N		Stable	4	M	14	5	3	no riffles					

Appendix M. Sampling schedule for stream stability cross-section monitoring.

Table M-1. Sampling schedule through 2007 for stream stability cross-sections.
Only Adair Creek was sampled in 2007 (bold).

	Redmond Ridge			Trilogy			
	Mackey	**Rutherford**	**Evans Central**	**Adair (NED)**	**Wallace (SED)**	**Colin South (SWD)**	**Colin North (NWD)**
Construction Start	**1998**	**1999**	**2000**	**2002**	**2001**	**2001**	**2003**
75% buildout	**Sept '01**	**Oct '03**	**Oct '05**	**Nov '06**	**Sept '05**	**Aug '02**	**Oct '06**
Preconstruction	1992	1992 1993 1998	1992 1993 1998 1999	1991 1992 1998 1999 2000 2001	1992 1993 1998 1999 2000	1998 1999 2000	1991 1992 1998 1999 2000 2001 2002
During construction	1998 1999 2000	1999 2000 2001 2002	2000 2002	2002 2005 2006	2002		2006
Post-development	2002 2005 2006	2005 2006	2005 2006	**2007**	2005 2006	2002 2005 2006	

Appendix N. Water quality sampling schedule

Table N-1. Schedule for the annual January – April water quality sampling through 2007.
75% buildout was determined by Richard Lowe (Lowe 2005, 2008) and post-development is defined as after 75% subbasin buildout.

	Redmond Ridge			**Trilogy**			
	Rutherford	**Evans Central**	**BBC**	**Adair**	**Wallace**	**Colin South**	**Colin North**
WQ Sites	EC-3, 18F	EC-61, EC-4, 18B	BBC-52, BBC-45 u/s & d/s	ADCW1, 53A u/s	SR-24 A,B, & C, 53C, 53B	BBC-44 u/s & center, 02D	BBC-26 u/s & d/s
Construction Start **75% buildout**	1999 Oct '03	2000 Oct '05	2001 TBD	2002 Nov '06	2001 Sept '05	2001 Aug '02	2003 Oct '06
Preconstruction				2002			2002 2003
During construction	2002 2003	2002 2003 2004 2005	2002 2003 2004 2005 2006 **2007**	2003 2004 2005 2006	2002 2003 2004 2005	2002	2004 2005 2006
Post-development	2004 2005 2006 **2007**	2006 **2007**		**2007**	2006 **2007**	2003 2004 2005 2006 **2007**	**2007**

Table N-2. Schedule for the continuous water quality sampling through 2007.
75% buildout was determined by Richard Lowe (Lowe 2005, 2008) and post-development is defined as after 75% subbasin buildout.

	Redmond Ridge		Trilogy			
	Rutherford	**Evans Central**[95]	**Adair**	**Wallace**	**Colin South**	**Colin North**
Gage Site	18F	18B	53A	53B & 53C[96]	02D	02C
Construction start	1999	2000	2002	2001	2001	2003
75% buildout	Oct '03	Oct '05	Nov '06	Sept '05	Aug '02	Oct '06
Preconstruction			1998 1999 2000 2001			2001 2002
During construction	2001 2002 2003	2000 2001	2002 2003 2004 2005 2006	2001 2002 2003 2004 2005	2001 2002	2003 2004 2005 2006
Post-development	2004 2005 2006 **2007**		**2007**	2006 **2007**	2003 2004 2005 2006 **2007**	**2007**

[95] Continuous temperature monitoring was not required at Evans Central (18B), however it was monitored from 2000-2001. The recorder measured temperature in a stilling well rather than the stream directly.
[96] Wallace Creek North (53C) was monitored for continuous temperature from 2002 to 2004, but because this creek goes dry in the summer when high temperatures are most likely, the temperature monitoring was discontinued.

Appendix O. Continuous temperature data for Wallace North (53C) and Evans Central (18B) Creeks.

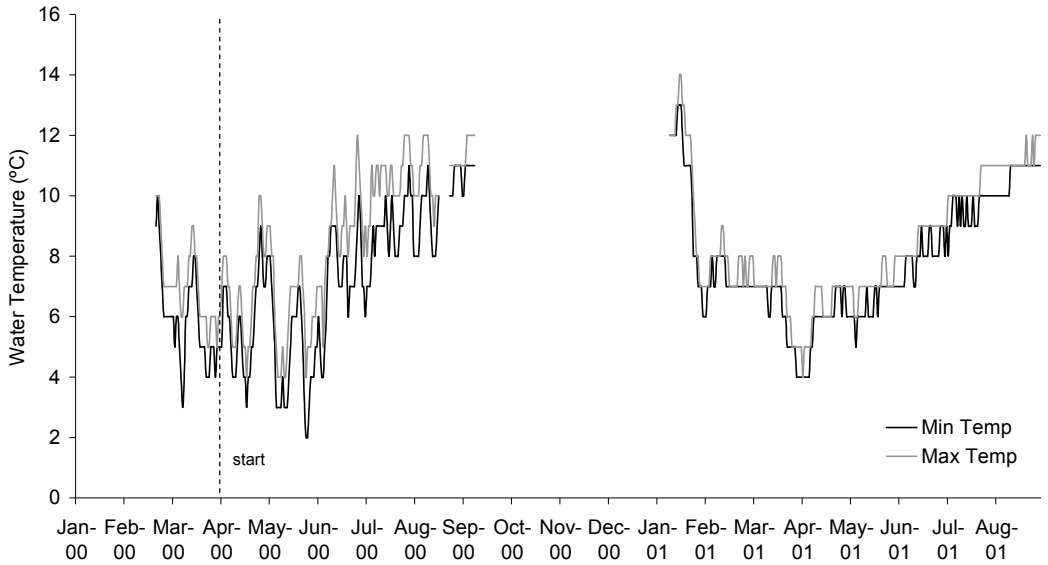

Figure O-1. Temperature data at Evans Central South Weir (2000-2001).
UPD construction commenced in late spring/early summer 2000 and 75% buildout was reached in October 2005. The continuous temperature recording device at gage station 18B was removed in 2001.

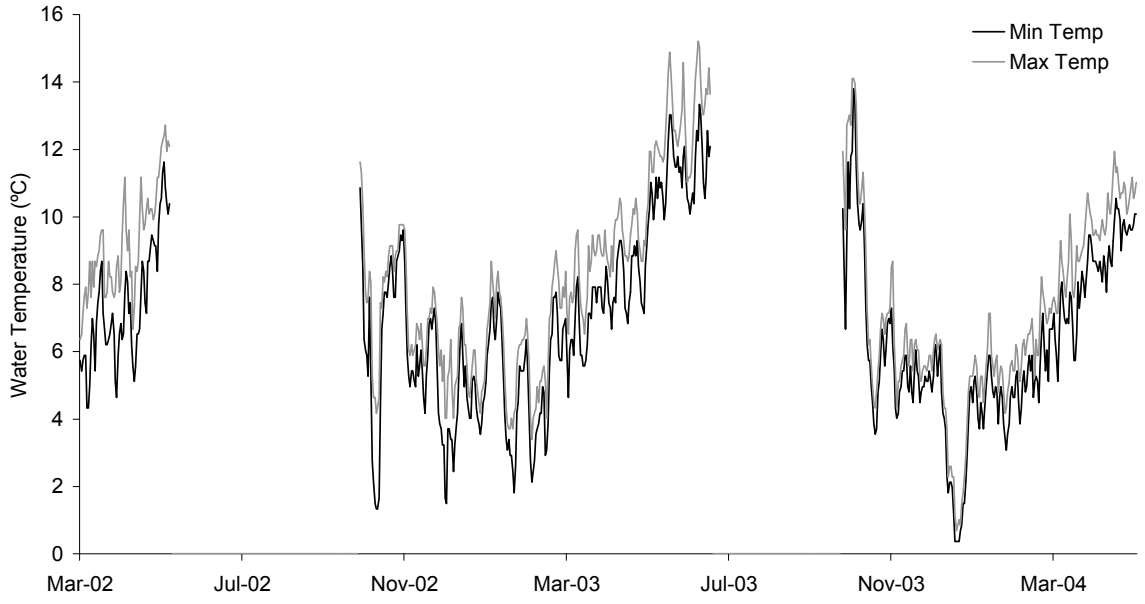

Figure O-2. Temperature data at Wallace Creek North (2002-2004).
UPD construction commenced in late spring/early summer 2001 and 75% buildout was reached in September 2005. Wallace Creek North runs dry during the summer months; therefore the continuous temperature recording device at gage station 53C was removed in 2004.

Appendix P. 2002-2006 stream pH measurements below state criteria of 6.5.

Table P-1. 2002-2006 stream pH measurements below state criteria of 6.5.
Measurements were collected with pH litmus paper and converted using multiplier 1.242 for comparison to 2007 Hydrolab data. pH criteria are set by Washington Department of Ecology (Washington Department of Ecology 2006).

Site ID	Date	pH
02D, Colin South	1/23/2002	5.8
02D, Colin South	2/20/2002	5.8
02D, Colin South	4/30/2002	6
02D, Colin South	2/5/2003	5.8
02D, Colin South	2/26/2003	5.8
02D, Colin South	4/28/2003	6.2
02D, Colin South	2/3/2004	5.8
02D, Colin South	3/2/2004	5.8
02D, Colin South	4/21/2004	6.2
02D, Colin South	2/2/2005	6.2
02D, Colin South	3/1/2005	6.2
02D, Colin South	4/7/2005	6.2
02D, Colin South	1/26/2006	6.4
02D, Colin South	2/1/2007	6.1
02D, Colin South	2/27/2007	6.4
02D, Colin South	5/1/2007	6.2
18B, Evans Central	2/21/2002	5.8
18B, Evans Central	4/30/2002	6.2
18B, Evans Central	2/5/2003	5.8
18B, Evans Central	2/26/2003	5.8
18B, Evans Central	4/28/2003	5.8
18B, Evans Central	2/3/2004	5.5
18B, Evans Central	3/2/2004	5.5
18B, Evans Central	4/26/2004	5.8
18B, Evans Central	2/28/2005	5.8
18B, Evans Central	4/4/2005	6.2
18B, Evans Central	1/24/2006	6.2
18B, Evans Central	1/31/2007	5.7

Site ID	Date	pH
18B, Evans Central	2/26/2007	6
18B, Evans Central	4/30/2007	5.5
18F, Rutherford	2/5/2003	6.2
18F, Rutherford	2/3/2004	6.2
18F, Rutherford	3/2/2005	6.2
53A, u/s; Adair	1/23/2002	6.2
53A, u/s; Adair	2/20/2002	6.2
53A, u/s; Adair	2/5/2003	6.2
53A, u/s; Adair	2/26/2003	6.2
53A, u/s; Adair	2/3/2004	6.2
53A, u/s; Adair	3/2/2004	6.2
53A, u/s; Adair	4/5/2005	6.2
53A, u/s; Adair	2/1/2007	6.3
53A, u/s; Adair	5/1/2007	6.4
53B, Wallace West	2/21/2002	5.8
53B, Wallace West	4/30/2002	6.2
53B, Wallace West	2/5/2003	5.8
53B, Wallace West	2/26/2003	6.2
53B, Wallace West	4/28/2003	6.2
53B, Wallace West	2/3/2004	6.2
53B, Wallace West	3/2/2004	6.2
53C, Wallace North	2/21/2002	5.8
53C, Wallace North	4/30/2002	6.2
53C, Wallace North	2/5/2003	5.8
53C, Wallace North	2/26/2003	5.8
53C, Wallace North	4/28/2003	6.2
53C, Wallace North	2/3/2004	5.8
53C, Wallace North	3/2/2004	6.2

Appendix Q. 2007 water quality data for in situ parameters

Table Q-1. Raw data from 2007 *in situ* water quality sampling.
Most parameters were measured using multiple methods. Hlab is Hydrolab water quality sonde, YSI is a YSI model 85 handheld system, testr2 is a handheld pH meter, and two different Hach 2100 turbidimeters were used. Late July and October sample periods were collected in 2007, but data are not presented in the report because this was the only year where third and fourth quarter sample dates were visited. Sites ending in '_r' are field replicates.

			Temperature		Dissolved Oxygen				Cond	Sp Conductivity		pH			Turbidity		Depth
			Hlab	YSI	Hlab	YSI	Hlab	YSI	YSI	Hlab	YSI	Hlab	testr2	4-7 paper	Lab unit	KSC unit	Hlab
Site ID	Date	Time	°C	°C	mg/L	mg/L	%	%	µS/cm	µS/cm	µS/cm						m
02D	2/1	14:35	2.27	2.5	12.26	11.61	88.7	85.3	18.4	29.4	32.2	6.28	6.0	4.7	1.69	2.49	
02D	2/27	14:06	4.64	4.8	11.55	11.51	90.7	89.7	21.2	32.4	34.5	6.60	6.2	5.0	2.39	1.59	-0.1
02D	5/1	12:14	10.32	10.4	10.08	10.92	89.9	97.8	22.9	30.7	31.8	5.91	7.0	5.2		3.52	-0.2
02D	7/31	12:01	14.26	14.3	7.57	7.59	73.3	74.5	34.9	42.7	43.8	6.47	6.7	5.0	2.42		0.1
02D	10/30	13:04	7.81	8.0	10.39	12.15	86.1	101.1	30.0	39.8	44.3	6.88		5.0	1.25		0.0
02D_r	2/27	14:15	4.65	4.8			89.9	90.5		32.3	21.2	6.61	6.2	5.0	0.98	1.35	
02D_r	5/1	12:24	10.39	10.5	9.98	9.65	89.1	87.5	22.9	30.8	31.7	5.96	7.0	5.2		3.43	-0.2
18B	1/31	13:00	0.93	1.1	7.76	7.58	54.2	53.5	18.0	29.1	LERR	6.03	5.5	4.4	1.30	3.01	
18B	2/26	11:01	4.70	4.9	8.59	8.51	67.7	66.4	19.9	31.6	32.4	6.18	5.5	4.7	0.61	0.85	0.3
18B	4/30	11:32	7.68	7.9	6.18	5.69	51.7	47.9	19.6	28.4	29.0	5.25	7.0	4.6		3.19	0.0
18B	7/30	10:30	13.40	13.4	1.32	1.16	12.8	11.2	58.2	68.7	68.4	5.77	6.7	4.7	2.51		-0.1
18B	10/29	10:30	6.35	6.6	4.55	4.64	37.0	37.8	32.9	50.8	50.7	5.77		4.5	1.11		0.1
18F	1/31	12:00	2.79	3.0	10.17	9.31	74.7	67.4	49.8	83.1	85.7	6.53	6.2	5.5	2.80	3.72	
18F	2/26	10:23	5.67	5.9	9.69	9.61	78.2	76.8	51.1	83.1	80.4	7.09	6.3	5.3	3.58	4.14	-0.1
18F	4/30	11:06	11.51	11.7	7.91	7.43	72.5	68.6	73.0	102.4	97.9	6.59	7.4	5.8		2.79	-0.1
53A, u/s	2/1	11:45	2.15	2.3	10.80	10.68	78.1	77.9	38.7	67.1	68.2	6.42	6.3	5.0	1.14	2.11	
53A, u/s	2/27	11:16	4.42	4.6	10.78	11.27	84.1	87.5	40.5	64.2	66.3	6.84	6.4	5.0	1.19	1.83	-0.1
53A, u/s	5/1	13:28	10.89	11.1	8.68	9.10	78.4	82.8	51.0	71.3	69.5	6.29	7.1	5.3		6.29	-0.1
53A, u/s	7/31	11:06	16.49	16.6	7.00	7.04	71.5	71.2	71.2	89.2	84.8	6.86	6.9	5.3	5.01		0.0
53A, u/s	10/30	11:12	7.56	7.7	9.12	10.89	75.0	91.6	52.3	74.8	78.0	6.60		5.2	3.96		0.1
53A_r	7/31	11:10	16.49	16.6	7.07	6.48	71.7	67.1	73.3	88.4	87.4	6.80	6.9	5.3	2.88		0.0
53A_r	10/30	11:19	7.59	7.8	9.10	11.11	74.8	93.2	52.8	74.7	78.7	6.70			3.60		0.1
53B	2/1	9:23	2.40	2.6	11.09	11.44	80.5	84.0	35.2	58.9	61.5	6.91	6.3	5.3	0.80	1.76	
53B	2/26	15:16	5.81	6.1	10.24	9.56	82.8	77.0	35.5	56.3	55.6	6.94	6.3	5.0	1.30	1.26	-0.2
53B	4/30	15:53	9.33	9.5	8.87	8.78	77.3	76.5	46.0	67.2	65.4	6.38	7.1	5.3		2.63	-0.2
53B	7/30	13:18	13.95	13.9	6.87	5.34	66.0	52.0	68.2	87.8	86.5	6.69	6.9	5.5	2.20		-0.1
53B	10/29	14:12	8.72	8.9	8.25	9.51	70.7	82.2	55.5	78.0	80.1	7.11		5.3	1.66		0.0
53B_r	7/30	13:25	13.80	13.9	7.42	6.11	71.5	59.0	68.9	88.4	87.4	6.78	6.9	5.5	4.48		-0.1
53B_r	10/29	14:20	8.73	8.9	8.29	9.00	70.9	78.9	46.5	77.6	67.1	7.04		5.3	2.07		0.1
53C	2/1	9:59	1.35	1.6	12.30	12.88	90.9	87.9	22.5	37.7	LERR	7.06	6.3	5.0	0.51	1.61	
53C	2/26	14:52	5.41	5.6	11.75	12.55	94.0	99.8	21.2	33.2	33.7	7.20	6.3	5.0	1.09	1.22	-0.1
53C	4/30	15:32	9.33	9.5	10.09	10.02	87.9	88.8	34.0	48.8	48.4	6.78	6.8	5.3		3.36	-0.1
53C	7/30	13:45	13.93	13.8	7.85	9.76	75.8	94.4	126.3	154.7	161.5	7.22	7.3	6.0	0.92		-0.1
53C	10/29	14:41	8.53	8.7	9.84	11.15	83.7	95.8	44.1	66.1	63.9	7.53		5.3	3.34		0.0
ADCW1	2/1	13:42	3.63	3.8	11.45	10.56	86.0	80.3	46.4	72.5	77.9	6.41	6.4	5.3	6.75	7.57	
ADCW1	2/27	12:48	5.15	5.4	11.44	11.44	91.1	90.4	45.4	71.3	72.6	7.09	6.6	5.3	0.98	1.10	-0.2
ADCW1	5/1	11:34	8.80	9.0	10.69	11.86	92.0	102.8	54.1	78.8	77.8	6.59	7.4	5.6		4.93	-0.2
ADCW1	7/31	10:35	12.57	12.7	9.38	9.39	87.8	88.6	72.5	96.3	94.8	6.77	7.1	5.8	2.09		0.0
ADCW1	10/30	12:14	8.58	8.8	10.57	12.71	89.3	109.3	57.7	99.4	83.6	7.11		5.4	0.82		0.1
BBC26 d/s	2/1	15:05	4.78	5.3	6.45	6.22	50.2	49.0	48.8	79.5	78.2	6.27	5.9	5.0	2.28	2.64	

Table Q-1 continued

			Temperature		Dissolved Oxygen				Cond	Sp Conductivity		pH			Turbidity		Depth
			Hlab	YSI	Hlab	YSI	Hlab	YSI	YSI	Hlab	YSI	Hlab	testr2	4-7 paper	Lab unit	KSC unit	Hlab
Site ID	Date	Time	°C	°C	mg/L	mg/L	%	%	µS/cm	µS/cm	µS/cm						m
BBC26 d/s	2/27	14:43	6.13	6.3	6.83	8.35	55.8	67.9	47.0	72.3	73.0	6.72	6.3	5.0	2.01	2.28	0.0
BBC26 d/s	5/1	12:58	14.24	14.2	5.38	5.40	52.6	52.6	59.1	76.2	74.3	6.16	6.9	5.3		1.43	0.0
BBC26 d/s	7/31	12:28	19.04	20.5	1.88	2.43	20.1	26.7	76.9	84.6	83.9	6.51	6.5	5.3	1.13		0.1
BBC26 d/s	10/30	13:32	8.78	9.0	3.12	4.01	26.5	34.9	63.4	85.8	91.5	6.59			1.14		0.2
BBC26 u/s	2/1	14:05	4.91	5.0	5.08	4.39	40.7	35.3	48.0	72.4	77.5	5.85	5.6	4.7	1.47	2.53	
BBC26 u/s	2/27	13:19	6.05	6.2	9.77	10.76	79.7	87.1	64.4	87.2	100.6	6.46	5.9	5.0	19.20	23.90	0.0
BBC26 u/s	5/1	13:55	15.38	15.7	8.01	8.26	80.0	83.2	53.1	65.7	64.5	6.31	7.1	5.4		1.45	-0.1
BBC26 u/s	7/31	11:33	16.54	16.5	1.03	1.02	10.5	10.4	53.3	63.2	63.7	6.32	6.4	5.0	2.42		0.0
BBC26 u/s	10/30	11:46	7.76	8.0	2.09	2.24	17.3	21.4	44.6	62.2	66.1	6.36		5.0	4.17		0.1
BBC44 center	2/1	13:05	2.28	2.6	1.03	1.47	7.6	10.4	23.3	41.6	40.8	5.49	5.1	4.0	2.84	2.46	
BBC44 center	2/27	11:51	3.76	3.4	4.07	6.23	31.4	46.6	24.7	40.4	42.2	5.63	5.3	4.4	0.55	0.87	-0.1
BBC44 center	5/1	11:03	11.28	11.8	6.71	9.10	60.6	83.6	21.4	33.4	29.5	5.05	6.0	4.7		1.46	-0.1
BBC44 u/s	1/31	16:10	1.42	1.6	3.47	3.34	24.5	23.0	11.7	17.7	LERR	4.89	5.0	4.4	3.50	5.87	
BBC44 u/s	2/26	14:12	5.00	5.3	4.40	4.56	35.2	36.0	11.0	15.9	17.5	5.47	4.9	4.4	0.69	0.80	0.2
BBC44 u/s	4/30	14:48	9.32	9.5	2.76	3.15	24.4	27.8	14.4	19.7	20.5	4.57	5.1	4.6		2.47	0.1
BBC45 d/s	1/31	15:51	3.33	1.7	4.89	4.24	34.7	30.8	12.2	18.3	LERR	4.99	4.9	4.0	1.21	0.71	
BBC45 d/s	2/26	13:47	5.40	6.9	7.22	7.47	57.7	61.0	10.5	14.3	15.9	5.56	4.9	4.4	1.96	1.73	0.1
BBC45 d/s	4/30	14:25	12.44	13.8	6.02	6.40	56.2	61.5	13.5	16.4	17.2	4.66	5.7	4.6		5.61	0.0
BBC45 d/s	7/30	12:47	18.15	20.9	0.13	10.53	1.5	126.0	17.4	86.5	18.8	5.58	6.1	4.4	8.56		0.4
BBC45 d/s	10/29	12:40	7.36	7.5	6.94	7.16	57.4	59.5	15.9	19.7	20.8	5.61		4.5	4.01		0.0
BBC45 u/s	1/31	15:16	3.75	3.8	5.08	4.51	38.4	33.9	14.1	19.2	23.6	5.45	5.2	4.4	0.46	0.94	
BBC45 u/s	2/26	13:20	5.41	5.7	6.70	6.98	53.7	55.6	11.4	17.5	18.0	5.85	5.1	4.7	0.87	1.00	-0.1
BBC45 u/s	4/30	13:58	11.40	12.3	1.57	3.28	14.3	31.0	17.4	31.5	23.0	5.33	6.1	4.7		2.27	-0.1
BBC45 u/s	7/30	12:24	15.28	15.0	0.74	1.18	7.5	12.2	64.8	86.3	80.3	6.34	5.9	4.7	7.97		-0.1
BBC45 u/s	10/29	12:13	7.89	8.1	3.17	2.95	26.3	25.0	22.6	33.2	33.6	5.82		4.6	4.10		-0.1
BBC52	1/31	14:50	4.04	4.5	6.96	6.43	51.9	49.4	15.9	19.3	26.0	5.35	5.0	4.4	1.15	1.56	
BBC52	2/26	12:58	5.67	5.9	8.14	8.26	65.2	66.0	11.0	15.9	17.4	5.95	5.6	4.7	0.68	1.18	-0.2
BBC52	4/30	13:38	13.67	14.6	5.42	6.02	51.9	60.1	13.3	15.5	16.6	5.06	6.5	4.8		2.83	0.0
BBC52	7/30	12:06	17.99	18.2	4.19	5.11	44.3	54.5	29.0	35.9	36.2	6.11	6.1	4.7	1.04		0.0
BBC52	10/29	11:50	7.10	7.2	6.11	7.00	50.9	58.0	12.0	16.0	18.2	6.18		4.6	1.58		0.1
EC3	1/31	10:43	4.61	4.2	2.93	3.13	22.6	23.8	42.6	78.2	70.7	6.29	5.7	5.0	0.65	0.94	
EC3	2/26	9:24	5.31	5.5	6.29	6.30	50.4	50.1	60.8	69.9	96.8	6.83	6.2	5.3	1.11	1.28	0.3
EC3	4/30	10:18	10.92	11.2	6.36	7.37	57.4	67.7	61.7	86.9	83.9	6.32	7.2	5.6		1.16	0.5
EC4	1/31	13:47	2.09	1.6	4.25	3.66	30.6	25.9	19.6	29.1	LERR	6.08	5.4	4.4	1.76	5.17	
EC4	2/26	11:33	5.13	5.4	7.34	7.64	58.2	60.4	19.3	30.3	30.8	6.18	5.3	4.7	0.58	1.15	-0.1
EC4	4/30	12:06	8.76	9.3	3.73	4.02	32.6	37.6	24.3	34.5	34.9	5.02	6.1	4.5		6.04	-0.2
EC4	7/30	11:00	14.12	14.4	4.25	5.07	41.1	50.7	129.1	167.1	114.5	6.73	6.9	6.0	9.11		-0.1
EC4	10/29	10:57	6.52	6.7	3.12	2.24	25.8	18.2	27.2	41.3	41.7	5.87		4.6	0.66		0.0
EC61	1/31	14:17	2.74	2.8	2.82	3.00	20.8	21.4	14.2	19.6	24.7	5.29	5.2	4.0	1.75	7.90	
EC61	2/26	11:59	4.73	5.0	5.80	5.67	45.6	44.4	11.3	16.5	18.4	5.84	5.1	4.4	0.64	0.85	0.1
EC61	4/30	12:27	11.10	12.0	2.15	3.06	19.0	29.5	18.6	24.5	24.8	5.17	6.3	4.7		6.70	0.1
EC61	7/30	11:18	17.19	17.3	1.85	1.77	19.5	18.4	23.8	28.0	27.9	6.16	6.2	4.7	2.96		0.0
EC61	10/29	11:16	7.14	6.6	2.28	1.78	17.3	14.6	21.6	32.8	33.5	6.21		4.7	3.65		0.3
EC61_r	2/26	12:10	4.73	5.1			45.5	45.0		16.6	18.3	5.84	5.1	4.4	0.68	0.92	
EC61_r	4/30	12:38	11.31	12.3	2.14	2.95	19.6	27.8	18.8	24.6	24.7	5.19	6.4	4.7		6.62	0.0
SR24A	2/1	10:20	2.94	3.2	1.10	1.03	8.2	7.6	46.4	77.9	79.4	6.24	5.6	4.7	4.05	4.57	
SR24A	2/27	9:54	4.63	4.5	6.76	7.12	52.4	55.0	29.4	45.8	48.4	6.37	6.1	5.0	1.55	2.56	-0.1
SR24A	5/1	10:10	9.79	10.0	1.76	2.00	14.8	17.8	37.9	61.2	60.6	5.69	6.4	5.0		8.15	-0.2
SR24A	7/31	9:41	13.81	13.9	1.03	1.34	10.0	12.9	55.5	684.0	70.5	6.09	6.3	4.7	4.37		-0.1

Table Q-1 continued

			Temperature		Dissolved Oxygen				Cond	Sp Conductivity		pH			Turbidity		Depth
			Hlab	YSI	Hlab	YSI	Hlab	YSI	YSI	Hlab	YSI	Hlab	testr2	4-7 paper	Lab unit	KSC unit	Hlab
Site ID	Date	Time	°C	°C	mg/L	mg/L	%	%	µS/cm	µS/cm	µS/cm						m
SR24A	10/30	10:24	9.18	9.6	0.93	1.03	8.4	9.0	70.0	91.2	99.5	6.27		5.0	11.60		0.0
SR24B	2/1	10:45	3.94	3.3	1.56	3.20	11.7	23.9	30.2	49.6	51.4	6.02	5.5	4.7	5.47	5.12	
SR24B	2/27	10:20	5.09	5.3	4.97	6.58	39.4	52.0	29.3	44.4	47.0	6.35	5.9	5.0	0.80	1.08	0.3
SR24B	5/1	9:49	13.13	13.3	5.47	5.77	52.0	55.1	38.6	50.0	49.9	5.89	6.9	5.1		2.22	0.0
SR24B	7/31	9:29	18.55	18.6	2.86	2.81	30.2	29.7	61.1	70.8	69.6	6.67	6.6	5.0	1.14		0.1
SR24B	10/30	10:11	7.36	7.5	3.39	4.03	27.6	33.7	36.4	49.9	54.6	6.52		5.0	0.88		0.3
SR24C	2/1	11:15	1.79	2.4	1.70	2.29	11.9	23.3	23.9	35.1	42.0	5.64	5.4	4.7	1.84	0.87	
SR24C	2/27	10:43	3.48	3.8	4.04	5.39	30.4	40.5	21.1	29.9	35.6	6.10	5.7	4.7	0.79	1.13	-0.2
SR24C	5/1	10:28	9.82	10.0	6.53	6.78	58.1	59.9	24.5	33.5	34.3	5.57	6.6	5.0		1.62	-0.2
SR24C	7/31	9:57	14.22	15.0	4.70	2.63	45.3	28.0	37.6	40.4	46.3	6.21	6.4	4.7	2.13		-0.1
SR24C	10/30	10:45	7.40	6.8	5.43	6.86	43.7	56.2	13.5	37.9	20.7	6.37		5.0	2.05		0.0

10/30/07 sampling: YSI dissolved oxygen was drifting, hydrolab specific conductivity calibrated with diluted solution, and the turbidimeter got wet inside, causing high readings relative to standards

LERR – error. Specific conductivity won't read when the water temperature is less than 2°C.

Appendix R. Dissolved oxygen results

One of the potential secondary construction impacts identified in the predevelopment EIS process was lowered dissolved oxygen concentrations in the wetlands related to nutrient inputs through sediment transport (Beak Consultants Incorporated 1995). However, these impacts were predicted to be effectively mitigated by wetland buffers, a lack of definitive surface channels, flat topography, and a thick forest duff layer.

As expected because of lentic conditions and increased decomposition, lower oxygen levels were observed in wetlands than in streams (Figure R-1) in all subbasins with both stream and wetland monitoring stations (i.e., Colin Creek South, Evans Creek Central, and Wallace Creek subbasins). Stream sites rarely had dissolved oxygen levels below state criteria standards for salmonid rearing and migration of 6.5 mg/L across the years (Washington Department of Ecology 2006) with only one violation in 2007 at Evans Creek Central (18B) with dissolved oxygen of 5.9 mg/L on April 30 (Table R-1). This site, which has six of the seven occurrences of stream dissolved oxygen less than 6.5 mg/L, is located at a weir that separates the wetland EC-3 from the creek (Figure R-2), and there is little opportunity for the slow moving wetland waters to become aerated as they transition to flowing waters.

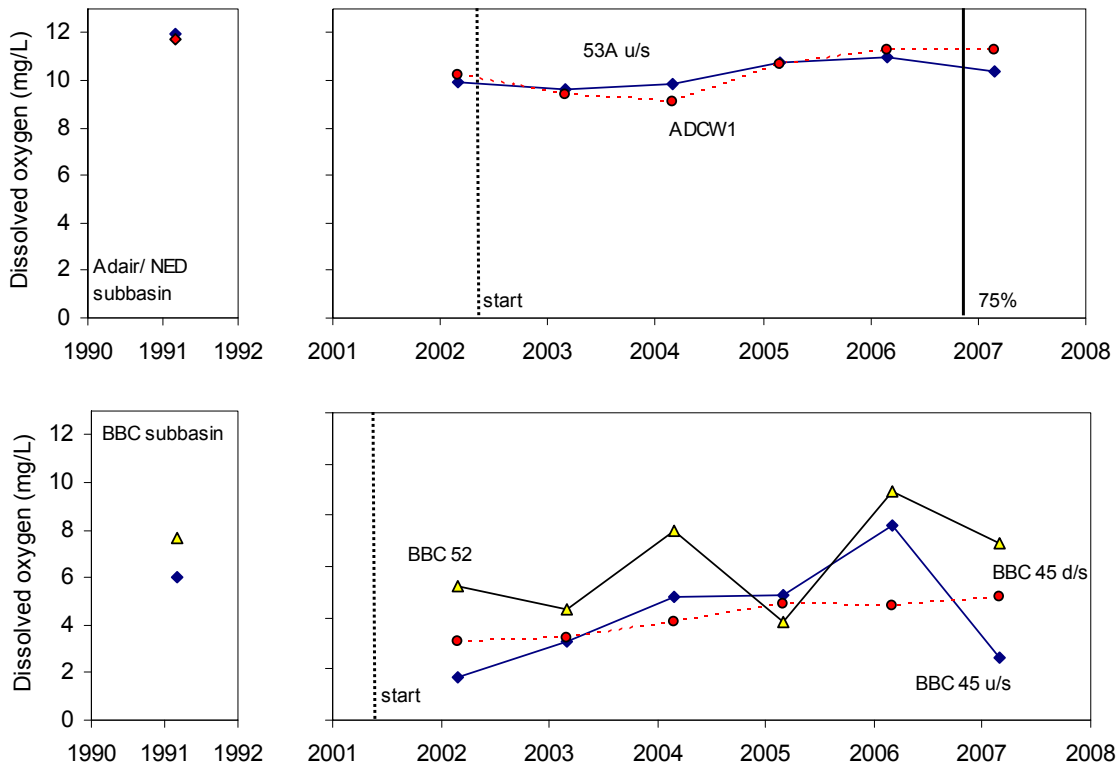

Figure R-1. Average dissolved oxygen (1991, 2002-2007). (Continued next page)
Data are averages of one to five measurements between January and April each year. Each graph represents a subbasin. The vertical dashed line labeled 'start' refers to the year construction and clearing began within the subbasin and the vertical solid line labeled '75%' represents the date when 75% buildout was reached within the subbasin. See Figure 52 for locations.

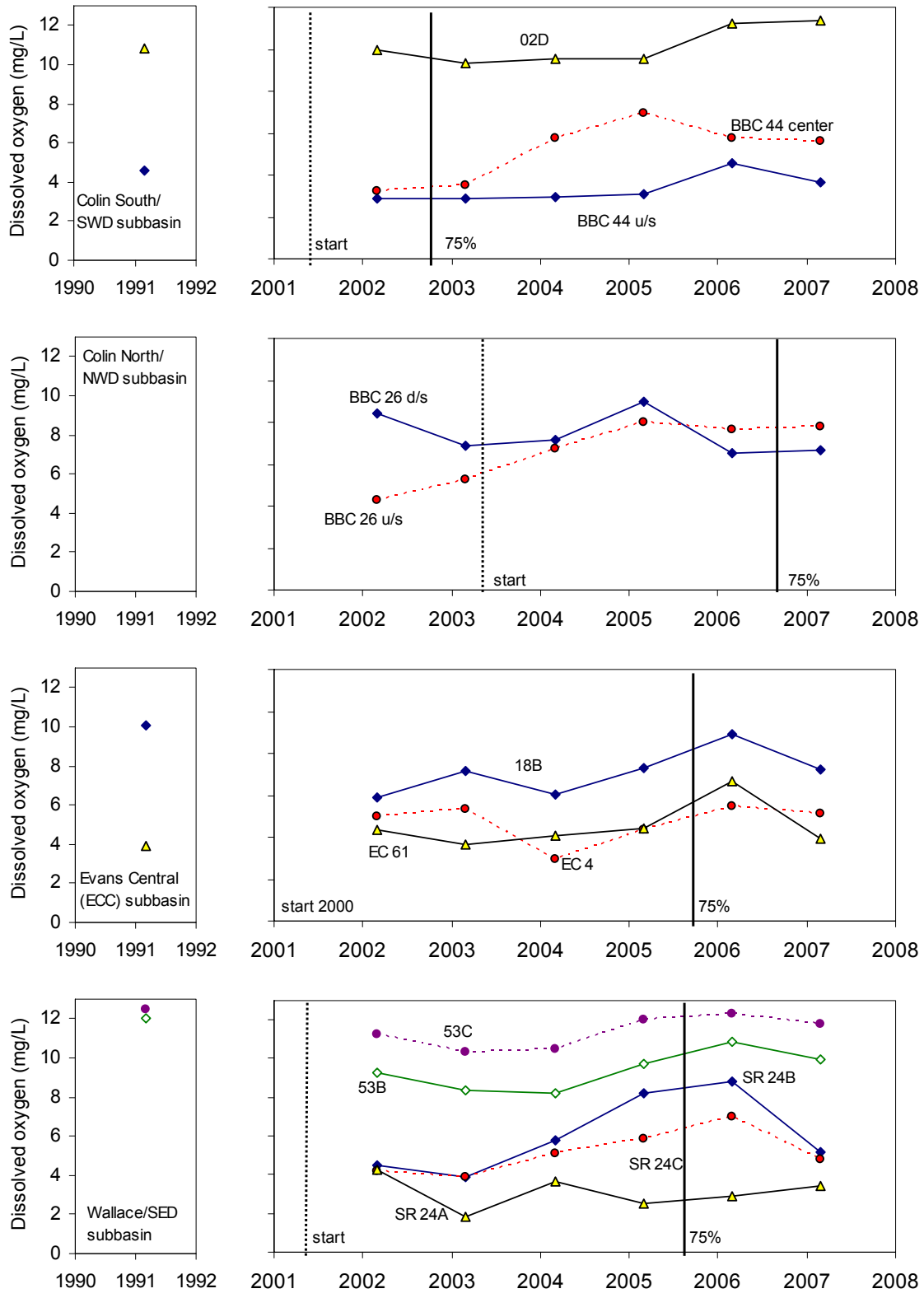

Figure R-1. Average dissolved oxygen. (Continued next page)

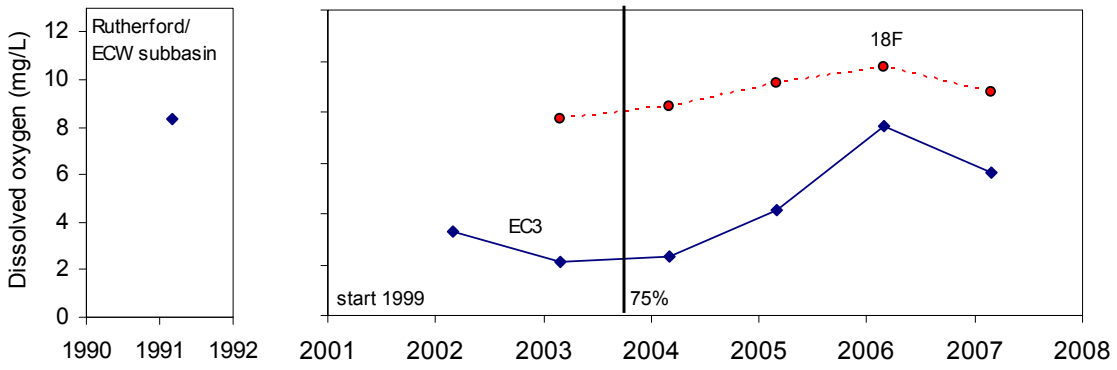

Figure R-1. Average dissolved oxygen. (Concluded)

Table R-1. Stream dissolved oxygen levels below 6.5 mg/L.
6.5 mg/L is the state standard for salmonid rearing and migration (Washington Department of Ecology 2006). Includes January – April sampling between 2002 and 2007.

Site ID	Date	Dissolved Oxygen (mg/L)
18B, Evans Central	4/30/02	5.04
18B, Evans Central	2/5/03	6.18
18B, Evans Central	2/3/04	6.25
18B, Evans Central	4/26/04	5.03
18B, Evans Central	1/26/05	5.76
18B, Evans Central	4/30/07	5.94
18F, Rutherford	4/26/04	6.28

Figure R-2. The south weir.
The south weir, gaging site 18B separates wetland EC-3 from Evans Creek Central. Water quality samples are collected just downstream of the weir.

Typically, decreases in dissolved oxygen concentrations are associated with water quality degradation in streams. However, in bogs increases in dissolved oxygen could be an early indicator of ecosystem changes where increases in the naturally low pH and nutrient levels could support conditions (e.g., decreased tannic acids) favoring increased photosynthesis that results in higher oxygen concentrations. However, changes in photosynthesis would not be expected during the first two sample periods in late January to early March when low levels of photosynthesis are expected in response to low winter light conditions. Additionally, although discrete, point measurements of dissolved oxygen may be helpful in identifying possible causes of specific anomalies (e.g., high fish or amphibian mortalities), three points are likely inadequate to summarize annual dissolved oxygen conditions to assess trends over time[97]. Keeping these caveats in mind, it appears that dissolved oxygen concentrations may be increasing at several wetlands including BBC-45 (u/s and d/s), BBC-44 (center), BBC-26 (u/s), and EC-3. Concentrations peaked in 2005 and 2006 at SR-24B and SR-24C before decreasing in 2007 (Figure R-1).

[97] Three points in a year do not provide enough data to account for temporal and measurement variation and measurements were not taken during a standardized time of day. Sources of measurement error include oxygen calibration methods and how vigorously the YSI probe was stirred to ensure water flow across the measurement membrane. The lack of consistency in field personnel between years amplifies these sources of error. Hydrolab measurements, which do not require physical agitation of the probe, may be less influenced by changes in field personnel than measurements taken with a YSI sonde.

Appendix S. Continuous turbidity results

Predevelopment turbidity samples were very low (mean 2.0 nephelometric turbidity units [NTU] for Redmond Ridge) (Herrera Environmental Consultants Inc. 1992) and no adverse turbidity impacts were predicted from UPD development because of flat topography and mitigation methods such as stormwater pond detention, discharge via level spreaders and interflow, and groundwater infiltration (Beak Consultants Incorporated 1995). Mean turbidity levels were generally less than 6 NTU for a year at each site (Figure S-1).

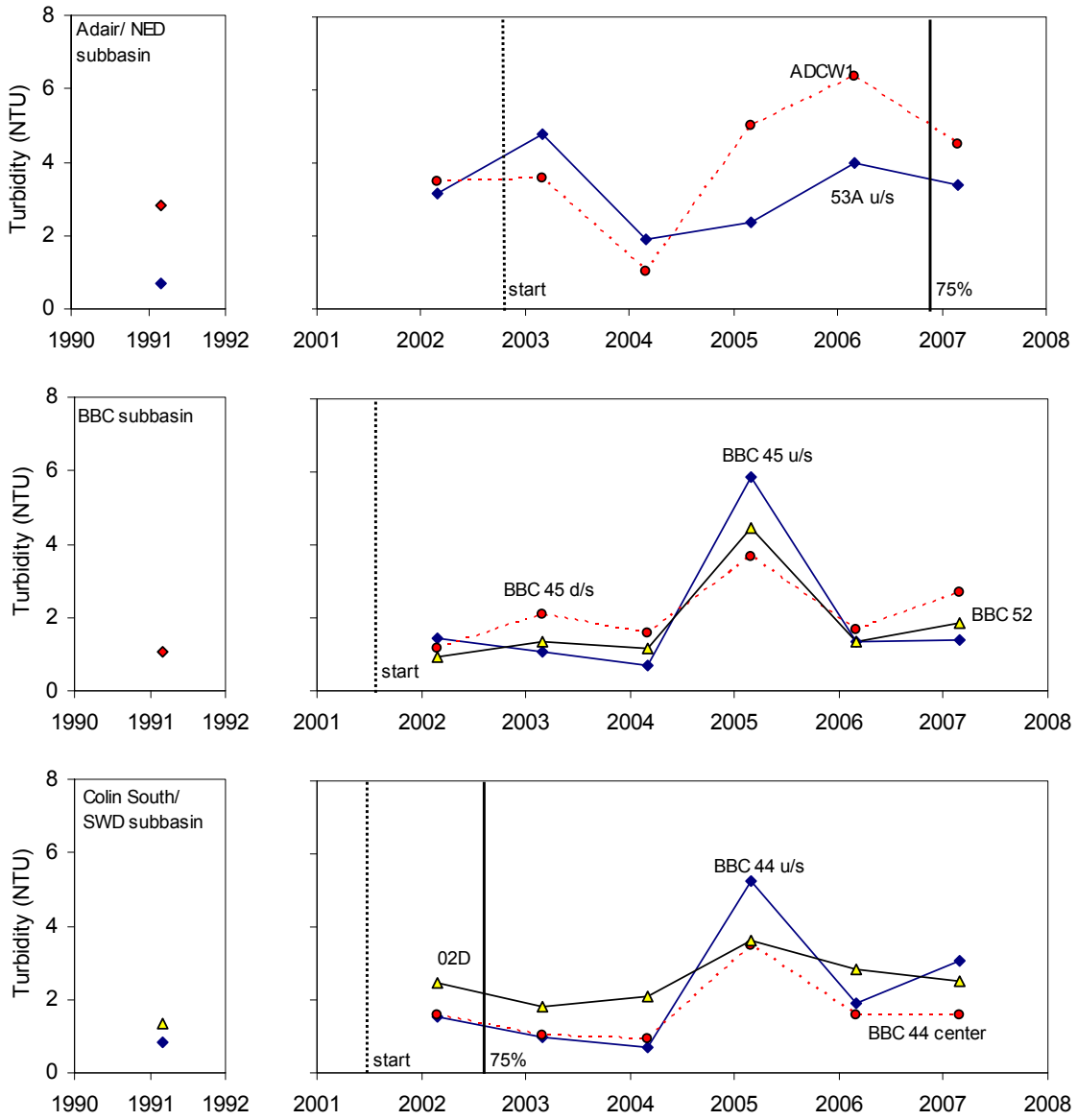

Figure S-1. Average annual turbidity (1991, 2002-2007). (Continued next page)
Averages are calculated from three measurements between January and April each year. Each graph represents a subbasin. The vertical dashed line labeled 'start' refers to the year construction and clearing began within the subbasin and the vertical solid line labeled '75%' represents the date when 75% buildout was reached within the subbasin. See Figure 52 for locations.

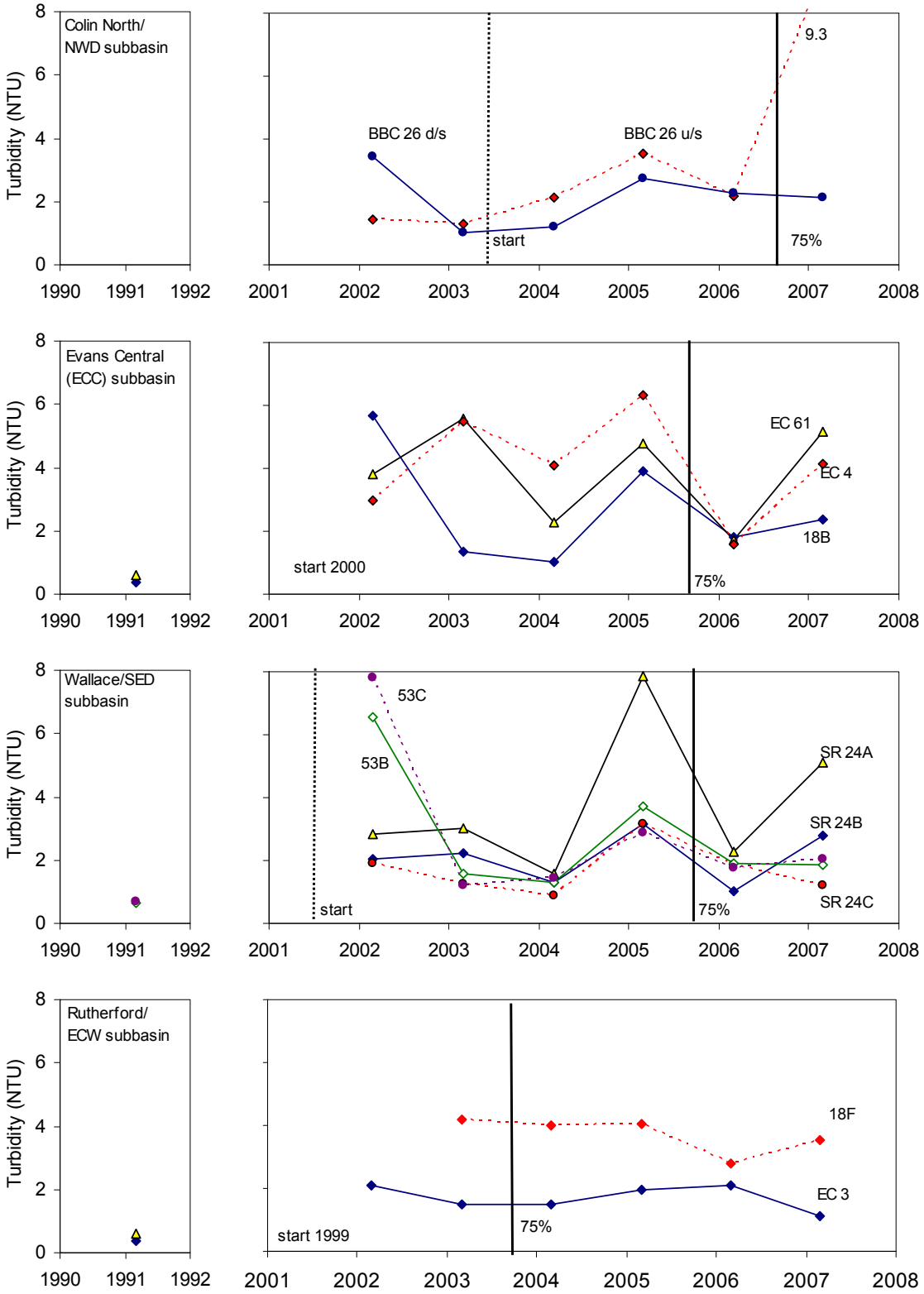

Figure S-1. Average annual turbidity (1991, 2002-2007). (Concluded).

The aquatic life turbidity criteria for salmonid rearing and migration (Washington Department of Ecology 2006) state that turbidity shall not exceed 10 NTU over background when the background is 50 NTU. Even if background levels were zero, turbidity has only exceeded 10 NTU nine times since 2002, and these exceedances were primarily at wetland locations (Table S-1). The highest level ever observed at the UPDs, 23.9 NTU, was at wetland BBC-26 u/s on February 27 where the turbidity was 23.9 NTU. Stormwater pond NWD4 was being drawn down by a level spreader device at a rate that did not allow infiltration and the turbid stormwater had a direct surface connection to BBC-26 at the sampling location (Figure S-2). The pumps were immediately turned off and this violation was reported to Bob Kelley, the onsite UPD inspector who insured that the construction contractors slowed down the rate of pumping to allow infiltration through the 200-ft. (60-m) wetland buffer. The turbidity level on 5/1/07 had dropped to 1.45 NTU.

Table S-1. Turbidity observations exceeding 10 NTU.
Data are from January to April sampling between 2002 and 2007 at 20 UPD stream and wetland locations.

Site ID	Date	Turb (NTU)
BBC-26 u/s	2/27/07	23.9
SR-24A	2/28/05	17
53C	2/21/02	13.8
EC-61	4/28/03	13.7
BBC-44 u/s	2/28/05	13.4
53B	2/21/02	13.3
EC-4	4/4/05	11.2
EC-61	2/28/05	10.8
BBC-45 u/s	4/4/05	10.5

Figure S-2. Level spreader near facility NWD4 in 2007.
This level spreader was dispersing water drained from stormwater pond NWD4 on February 27, 2007 creating a direct surface connection to BBC-26 and contributing to high turbidity readings on that date. The pumping volume was decreased to allow infiltration through the wetland buffer.

In addition to January through April point sampling of turbidity, attempts were made to monitor turbidity at several continuous stream gaging locations. These results are shown in Figures S-3 to S-6, where the minimum turbidity reading of the day is shown. This value tends to be most indicative of the actual stream condition.

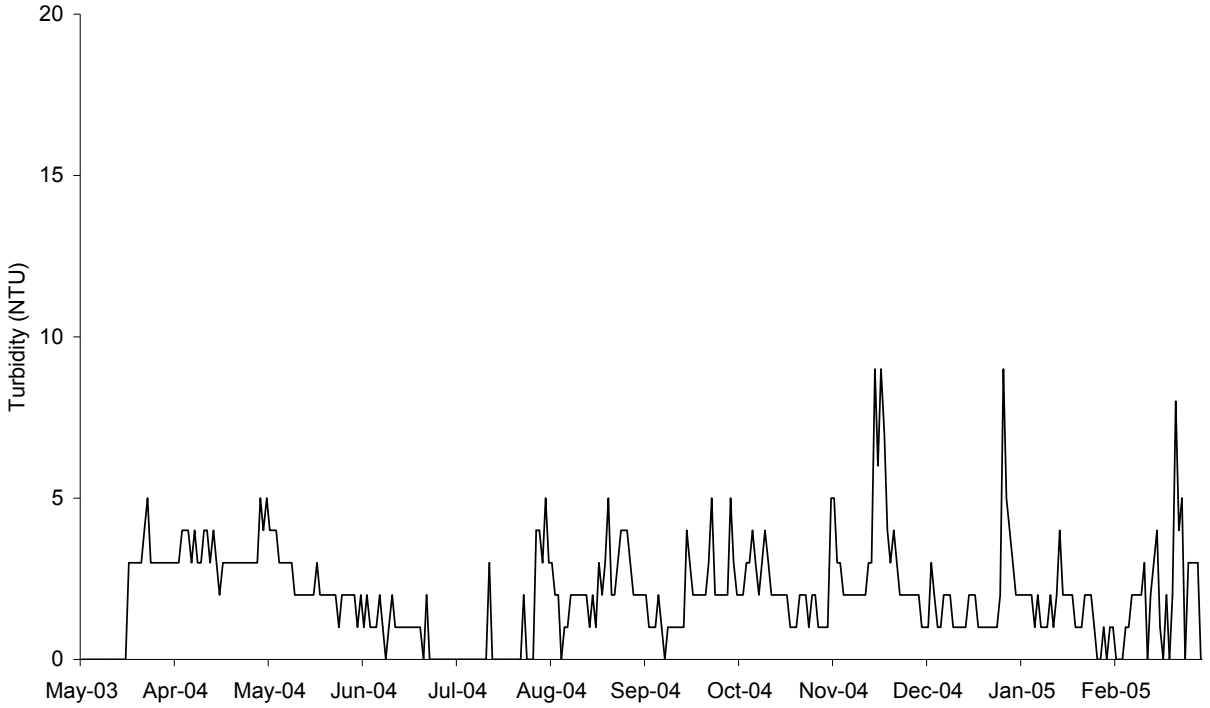

Figure S-3. Adair Creek (gage 53A) minimum daily turbidity levels (2004-2005).

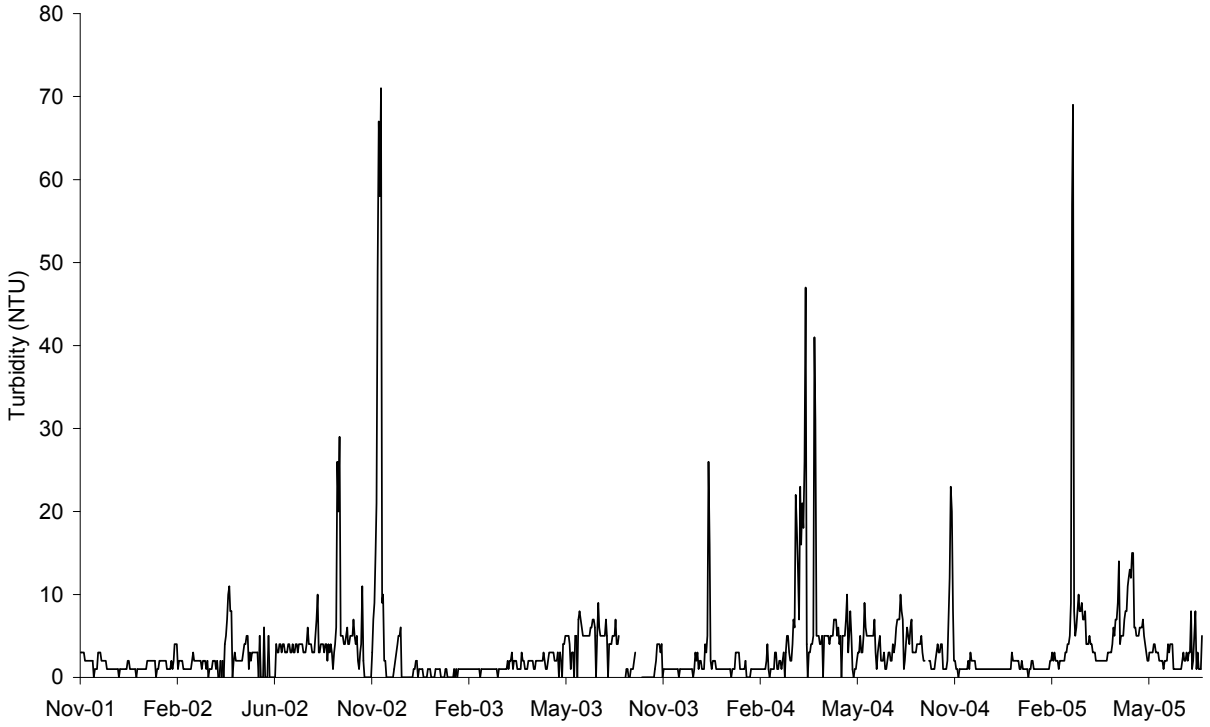

Figure S-4. Colin Creek South (gage 02D) minimum daily turbidity levels (2001-2005).

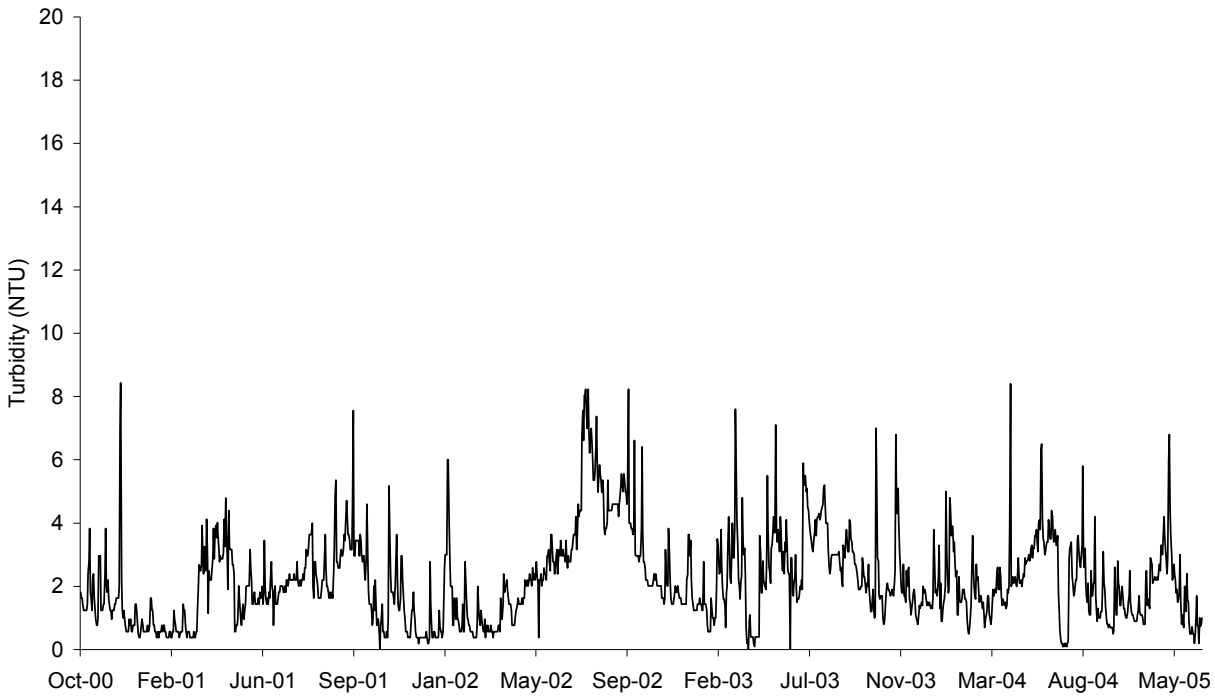

Figure S-5. Rutherford Creek (gage 18F) minimum daily turbidity levels (2000-2005).

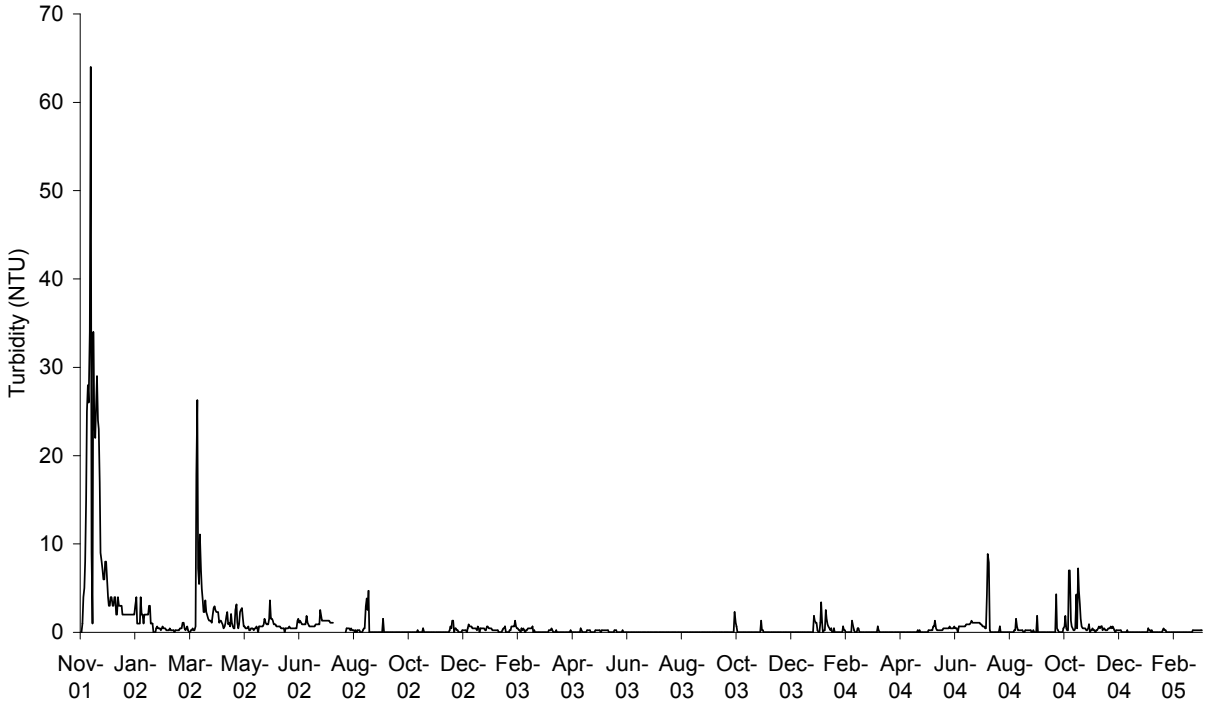

Figure S-6. Wallace Creek West (gage 53B) minimum daily turbidity levels (2001-2005).

Appendix T. 2007 metals data

Table T-1. Total metals and associated parameters.
Results were determined by ICP (inductively coupled plasma) analysis of metal/metalloid particulates methods. Units are µg/L except for hardness, which is in $CaCO_3$/L. Italics represent values less than RDL[98].

Locator	Collection Date	Al	Ba	B	Ca	Cr	Co	Cu	Hard-ness	Fe	Pb	Mg	Mn	Ni	P	K	Na	Sr	S	Ti	V	Zn
02D	2/1/07	*200*	8.1		1940				9.42	384		1110	37.3				2530		781			
02D	2/27/07	*180*	6.92		1980				9.93	334		1210	14.1				2740		686			
02D	5/1/07	*280*	7.63		2200				10.7	1000		1270	81.5			750	2620	*20*	484	*6.7*		
02D	7/31/07	*290*	10.3		3750				17.2	902		1890	293			*700*	3130	*30*		*7.2*		
02D	10/30/07	*200*	8.27		2920				14.9	767		1860	58.6				3230	*29*	1080			
18B	1/31/07	*250*	13.6		2170			*4.6*	9.36	*250*		955	10.2				3130	*24*	608			
18B	2/26/07	*200*	11.7		1850				8.17	*190*		865	12.9				3410	*27*	558			
18B	4/30/07	*350*	16.2		2520				10.6	377		1060	25.2				3130	*27*	395	*4.5*		*7.8*
18B	7/30/07	614	42.8		6510				27	1330		2620	292		*160*	945	5190	67.8		*14*		*11*
18B	10/29/07	663	32.8		4790				20.5	773		2080	43.8		*61*		4710	52	2110	*6.9*		*8.6*
18F	1/31/07		11		6570				30.2	701		3360	58.7			*2200*	5060	*57*	1110			
18F	2/26/07	*190*	10.1		6200				29.6	801		3420	90.9			*2200*	5090	*57*	1060			
18F	4/30/07		8.78		8210				39.1	934		4520	102			1930	5550	66.7	859			
53A u/s	2/1/07	*100*	7.47		4730				21.2	*150*		2290	16.8				4980	*39*	1850			
53A u/s	2/27/07	*120*	6.7		4460				20.4	*150*		2250	13.1				5130	*46*	2110			
53A u/s	5/1/07	676	11.9		5640				25	890		2650	84.1			*700*	5170	*49*	1800	28.3		
53A u/s	7/31/07	*430*	11.3		7690				32.4	937		3210	406			879	5850	65.8		*17*		
53A u/s	10/30/07	*370*	8.41		5580				25.3	466		2760	63.9				6270	*46*	2800	*16*		
53B	2/1/07		9.36		4670				20.5	*210*		2140	31.6				4410	*38*	1320			
53B	2/26/07		8.32		4220				19	280		2050	41.9				4190	*43*	1150			
53B	4/30/07		8.76		5560				23.9	294		2440	47.3			*510*	4540	*46*	910			
53B	7/30/07	*270*	20		8930				36.3	2130		3390	1540		*57*	*560*	5300	70.1		*8.9*		
53B	10/29/07		11		6600				28.4	502		2910	289				5520	55.6	1010			
53C	2/1/07	*140*	7.51		2980				12.8	*100*		1290	*5*				2970	*28*	1200			*23*
53C	2/26/07	*210*	6.9		2530				10.9	*180*		1120	11.5				2800	*32*	913			*25*
53C	4/30/07	1320	19.7		4680				19.5	1230		1890	240		*94*	*590*	3450	*40*	988	42.3		70.7
53C	7/30/07		18.2		17200				68.4			6180	*5.1*			1220	9340	123				*8.1*
53C	10/29/07	*190*	10.4		5980				25	*190*		2450	16.4				3930	51.1	1860	*5*		*16*
ADCW1	2/1/07	1460	20.4		6430				29.2	1410		3200	137		*110*		5330	*53*	1910	*57*		*5.2*
ADCW1	2/27/07		7.35		5030				23.1	*75*		2550	*7.6*				5460	*48*	1950			
ADCW1	5/1/07	*130*	8.29		6370				28.9	*180*		3140	22.9			*620*	5220	*50*	1840	*4.2*		
ADCW1	7/31/07	*400*	13.3		8830				37.8	436		3830	61.6		*78*	*710*	5780	65.4		*14*		
ADCW1	10/30/07	*130*	10.2		6720				30.4	*150*	*42*	3310	19.2				5570	54.9	2080	*4.1*		*6.1*
BBC26 d/s	2/1/07		11.6		5950				24.1	284		2240	19.5				6360	*50*	1540			
BBC26 d/s	2/27/07		10.3		5330				22.1	256		2140	19.3				6120	*55*	1300			
BBC26 d/s	5/1/07		12.1		6030				24.5	349		2300	30.3			1010	5770	52.9	1220			
BBC26 d/s	7/31/07		13.2		8000				30.5	568		2560	39.8			*690*	7310	69				
BBC26 d/s	10/30/07		12		7520				29.8	340		2670	18				7790	70.1	1540			

[98] RDL is reporting detection limit.

Table T-1 continued

Locator	Collection Date	Al	Ba	B	Ca	Cr	Co	Cu	Hard-ness	Fe	Pb	Mg	Mn	Ni	P	K	Na	Sr	S	Ti	V	Zn
BBC26 u/s	2/1/07		11		4160				17.4	270		1700	29				7740	36	1390			
BBC26 u/s	2/27/07	1260	24.3	74	5040				20.2	997		1840	18.5		88	2300	13400	53	4110	49		5.1
BBC26 u/s	5/1/07		7.57		5060				21.4	240		2130	11.8			740	5220	47	1220			
BBC26 u/s	7/31/07		11.6		6170				25.6	988		2470	193		140	480	3760	52.2				
BBC26 u/s	10/30/07	110	158		5960				26.5	1340		2820	208		140		6510	61.4	693			6.3
BBC44 center	2/1/07	330	8.67		2360				11.5	1100		1360	43.4				3780	21	676			5.6
BBC44 center	2/27/07	130	4.2		2170				11.5	285		1480	14.5				4040	25	759			
BBC44 center	5/1/07	170	3.1		1600				8.55	314		1110	10.2			1130	3600	16	440			6.6
BBC44 u/s	1/31/07	330	8.3		1080				4.94	464		545	40.1				2000		493			7.5
BBC44 u/s	2/26/07	150	5.14		770				3.57	338		399	30.2				1700		250			
BBC44 u/s	4/30/07	460	9.39		960			19	4.88	838		603	53.9		170	560	1800	11	315	17		24
BBC45 d/s	1/31/07	130	7.12		992				4.66	265		530	51				1700		473			
BBC45 d/s	2/26/07		3.4		680				3.31	240		392	31.5				1500		200			
BBC45 d/s	4/30/07	568	11.1		1420	3.3			6.29	1130		668	77.6		85	540	2100	13	299	10		10
BBC45 d/s	7/30/07	320	88.5		2000			6.7	9.6	1510		1120	97.1		210	1140	2100	24		9.5		28.8
BBC45 d/s	10/29/07	250	32.6		1290			4.8	6.29	729		746	136		150		1400	17	377	4.7		12
BBC45 u/s	1/31/07	180	14.2		1270				5.56	549		579	61				1700		575			
BBC45 u/s	2/26/07	180	7.27		1000				4.55	739		495	49				1600		311			
BBC45 u/s	4/30/07	300	9.27		1380				5.87	1410		589	146			270	1700	16	240			11
BBC45 u/s	7/30/07	2170	31.1		3550	4.4	3.5	4.8	15.2	20700		1530	1090		180	580	1900	37		85.3		74
BBC45 u/s	10/29/07	565	21.6		2520				10.6	4610		1050	448		68		1700	32	1260	18		99.1
BBC52	1/31/07	190	10.4		1330				5.81	388		603	72.5				1700		543			
BBC52	2/26/07	150	7.37		940				4.29	537		472	34.7				1600		314			
BBC52	4/30/07	190	7.16		1020				4.65	437		511	47.6			290	1600	10	252			9.9
BBC52	7/30/07		6.61		1480				7.34	1010		884	84.8			1540	3150	19				
BBC52	10/29/07	110	4.7		1160				5.75	358		693	39.9				1300	15	293			
EC3	1/31/07	120	13.5		5430				22.6	83		2210	24				4540	54	890			
EC3	2/26/07		11.4		9730				36.7	150		3020	20.3			2000	5290	90	1200			
EC3	4/30/07		8.8		8220				31.3	140		2620	24.6			1710	4810	72.6	917			7.4
EC4	1/31/07	1300	31.4		2570			4.7	11.1	1410		1130	52.1		282		3330	28	751	38		10
EC4	2/26/07	220	13.8		2290				9.36	240		883	12.7		180		3290	32	919			
EC4	4/30/07	500	36		6520			4.4	22	1380		1400	111		1050	1210	3320	42	736	11		17
EC4	7/30/07	15500	324		34900	18.6	17.9	29.1	120	17700	53	7900	3750	24	1910	6460	12900	282		428	26	81.8
EC4	10/29/07	506	27.3		4000				17	586		1700	60.1		75		3980	42	994	5.2		7.1
EC61	1/31/07	110	8.3		915			5.4	4.18	150		461	39.8				2500		594			
EC61	2/26/07		6.88		807				3.73	330		418	43.5				2000		240			
EC61	4/30/07	190	12.7		1560				6.65	1690		671	152		110	610	2200	18	293	5.6		5.9
EC61	7/30/07	230	12.7		2140				9.11	2500		913	120		76	520	2100	21		9.2		
EC61	10/29/07	220	15.8		2290				11.3	2730		1360	225		61		2690	28	268	8.2		
SR24A	2/1/07	1380	19.7		3820			8.1	18.3	10600		2120	580		220		3630	31	1010	54	11	9.1
SR24A	2/27/07	565	8.93		3280				15.9	1280		1870	111		66		3380	33	1130	35		
SR24A	5/1/07	230	8.79		3800				17.7	5610		1980	581		67	480	3640	30	355	6.8		
SR24A	7/31/07	470	14.3		5860				25.3	9970		2580	812		150	700	4920	48		18		
SR24A	10/30/07	310	18.3		6430		3.4		28.4	20800		3010	1690		200		4470	58.6	336	11		7.5
SR24B	2/1/07	350	9.18		3690			24.9	17.3	412		1960	95.7				3490	31	1230			7

Table T-1 continued

Locator	Collection Date	Al	Ba	B	Ca	Cr	Co	Cu	Hard-ness	Fe	Pb	Mg	Mn	Ni	P	K	Na	Sr	S	Ti	V	Zn
SR24B	2/27/07		5.66		3110				15.3	*220*		1830	22.4				3410	*28*	1130			
SR24B	5/1/07		6.38		3540			*7.4*	16.6	314		1890	38.6			976	3680	*28*	876			
SR24B	7/31/07		9.88		5570				25	619		2680	112		*65*	1160	4850	*43*				
SR24B	10/30/07		6.6		3610				18.1	325		2210	34.9				4250	*32*	812			
SR24C	2/1/07	*150*	8.37		2590				11.8	523		1300	227				2870	*23*	670			
SR24C	2/27/07	*120*	5.77		2140				9.85	845		1090	75.5				2690	*26*	601			
SR24C	5/1/07	*480*	8.41		2330				10.6	859		1160	153			*490*	2880	*20*	565	29.3		
SR24C	7/31/07		6.97		3370				14.6	1210		1500	295			*480*	3660	*25*				
SR24C	10/30/07	*220*	6.35		2820				13.2	804	*22*	1500	71.4				3390	*27*	458	*9.8*		

Metals are generally more soluble and therefore more bioavailable to harm organisms at lower pH, alkalinity, and hardness (Horner et al. 1994). Most of the wetlands sampled are naturally low pH, low alkalinity systems, and because the streams sampled drain these wetlands, they generally have low pH, alkalinity, and hardness too. Therefore, these systems are particularly vulnerable to relatively small amounts of metal inputs because there is little bicarbonate and carbonate for the metals to bind to, so the metals remain primarily in their toxic ionic state (Horner et al. 1994).

Predevelopment baseline measurements of dissolved metals concentrations from the early 1990s, when corrected for hardness, repeatedly exceeded Washington State water quality standards (WAC Chapter 173-201A 2003) for lead, zinc, and copper at a number of sample locations (see Appendix 4.3.1.2 of the Midpoint Report (King County 2006)). Data from the Puget Sound Wetlands and Stormwater Management Program from the late 1980s through the mid 1990s suggest that high levels of soil metals from 1988 to 1990 were not uncommon throughout the Puget Sound region (Reinelt and Horner 1990, Horner et al. 2001a), though substantial declines were observed by the mid 1990s[99].

Metals monitoring is not required in the Trilogy or Redmond Ridge monitoring plans (King County 1999, 2001); however, when hardness measurements were added in 2006, total metals data were made available. Most Washington state toxics criteria for metals are based on dissolved concentrations, however only total metals data are available for these monitoring locations. In addition, method detection limits[100] were often higher than acute toxicity criteria for copper, lead, and zinc. Results of total metals testing for copper, lead, and zinc are shown in Table T-2; elevated concentrations beyond criteria levels are highlighted in red text. Wallace Creek North (53C) consistently had elevated levels of zinc.

[99] These declines were likely associated with reductions in industrial air pollution point sources and automobile pollutants including the removal of lead as a fuel additive and the advent of emission controls and catalytic converters (Horner et al. 2001a).

[100] Method detection limit (MDL) is the minimum concentration where the analyte can be reliably distinguished from the blank (a false positive rate of </= 1%) (King County 2009).

Table T-2. Total copper, lead, and zinc (µg/L) relative to Washington state toxic criteria for dissolved metals. Criteria are hardness dependent. Numbers in red report the method detection limit (MDL) because lab results were <MDL[101]. Measurements highlighted in green are greatly elevated above the toxic criteria.

Site	Date	Hardness	Total Copper	Dissolved Cu acute	Dissolved Cu chronic	Total Lead	Dissolved Pb acute	Dissolved Pb chronic	Total Zinc	Dissolved Zn acute	Dissolved Zn chronic
02D	1/26/06	7.86	4	1.5	1.3	30	3.7	0.1	5	13.3	12.1
02D	2/28/06	8.08	4	1.6	1.3	30	3.8	0.1	5	13.6	12.4
02D	4/20/06	10.8	4	2.1	1.7	30	5.4	0.2	5	17.4	15.9
02D	2/1/07	9.42	4	1.8	1.5	30	4.6	0.2	5	15.5	14.1
02D	2/27/07	9.93	4	1.9	1.6	30	4.9	0.2	5	16.2	14.8
02D	5/1/07	10.7	4	2.1	1.7	20	5.3	0.2	5	17.2	15.7
18B	1/24/06	10.5	4	2.0	1.7	30	5.2	0.2	5	17.0	15.5
18B	2/28/06	12.4	4	2.4	1.9	30	6.3	0.2	5	19.5	17.8
18B	4/21/06	9.1	4	1.8	1.5	30	4.4	0.2	5	15.0	13.7
18B	1/31/07	9.36	4.6	1.8	1.5	30	4.5	0.2	5	15.4	14.0
18B	2/26/07	8.17	4	1.6	1.3	30	3.9	0.2	5	13.7	12.5
18B	4/30/07	10.6	4	2.1	1.7	20	5.2	0.2	7.8	17.1	15.6
18F	1/24/06	25.5	4	4.7	3.5	30	14.2	0.6	5	36.0	32.8
18F	2/28/06	27.5	4	5.0	3.8	30	15.5	0.6	5	38.3	35.0
18F	4/21/06	33.1	4	6.0	4.4	30	19.0	0.7	5	44.8	41.0
18F	1/31/07	30.2	4	5.5	4.1	30	17.2	0.7	5	41.5	37.9
18F	2/26/07	29.6	4	5.4	4.0	30	16.8	0.7	5	40.8	37.3
18F	4/30/07	39.1	4	7.0	5.1	20	22.9	0.9	5	51.6	47.2
53A,U/S	1/25/06	17.8	4	3.3	2.6	30	9.5	0.4	5	26.5	24.2
53A,U/S	2/28/06	19.5	4	3.6	2.8	30	10.5	0.4	5	28.6	26.2
53A,U/S	4/21/06	19.1	4	3.6	2.8	30	10.2	0.4	5	28.1	25.7
53A,U/S	2/1/07	21.2	4	3.9	3.0	30	11.5	0.4	5	30.7	28.1
53A,U/S	2/27/07	20.4	4	3.8	2.9	30	11.0	0.4	5	29.8	27.2
53A,U/S	5/1/07	25	4	4.6	3.5	20	13.9	0.5	5	35.4	32.3
53B	1/25/06	14.8	4	2.8	2.2	30	7.7	0.3	5	22.7	20.7
53B	2/28/06	19.7	4	3.7	2.8	30	10.6	0.4	5.2	28.9	26.4
53B	4/21/06	21.8	4	4.1	3.1	30	11.9	0.5	5	31.5	28.7
53B	2/1/07	20.5	4	3.8	2.9	30	11.1	0.4	5	29.9	27.3
53B	2/26/07	19	4	3.6	2.7	30	10.2	0.4	5	28.0	25.6
53B	4/30/07	23.9	4	4.4	3.3	20	13.2	0.5	5	34.0	31.1
53C	1/25/06	11.4	4	2.2	1.8	30	5.7	0.2	25.9	18.2	16.6
53C	2/28/06	12.5	4	2.4	1.9	30	6.3	0.2	32	19.7	17.9
53C	4/21/06	13.7	4	2.6	2.1	30	7.0	0.3	32.5	21.2	19.4
53C	2/1/07	12.8	4	2.5	2.0	30	6.5	0.3	23	20.1	18.3
53C	2/26/07	10.9	4	2.1	1.7	30	5.4	0.2	25	17.5	16.0
53C	4/30/07	19.5	4	3.6	2.8	20	10.5	0.4	70.7	28.6	26.2
ADCW1	1/26/06	30.9	4	5.6	4.2	30	17.6	0.7	5	42.3	38.6
ADCW1	2/28/06	33.7	4	6.1	4.5	30	19.4	0.8	5	45.5	41.6
ADCW1	4/20/06	24.3	4	4.5	3.4	30	13.4	0.5	5	34.5	31.5

[101] The MDL for lead was lowered from 30 to 20 µg/L in April 2007 to reflect the lower MDLs achievable for new ICP technology brought on-line I n 2003 (King County 2007).

Table T-2 continued

Site	Date	Hardness	Total Copper	Dissolved Cu acute	Dissolved Cu chronic	Total Lead	Dissolved Pb acute	Dissolved Pb chronic	Total Zinc	Dissolved Zn acute	Dissolved Zn chronic
ADCW1	2/1/07	29.2	4	5.3	4.0	30	16.5	0.6	5.2	40.3	36.8
ADCW1	2/27/07	23.1	4	4.3	3.2	30	12.7	0.5	5	33.1	30.2
ADCW1	5/1/07	28.9	4	5.3	3.9	20	16.3	0.6	5	40.0	36.5
BBC26D/S	1/26/06	21.8	4	4.1	3.1	30	11.9	0.5	5	31.5	28.7
BBC26D/S	2/28/06	20.9	4	3.9	3.0	30	11.3	0.4	5	30.4	27.7
BBC26D/S	4/20/06	22.5	4	4.2	3.2	30	12.3	0.5	5	32.3	29.5
BBC26D/S	2/1/07	24.1	4	4.5	3.4	30	13.3	0.5	5	34.3	31.3
BBC26D/S	2/27/07	22.1	4	4.1	3.1	30	12.1	0.5	5	31.8	29.1
BBC26D/S	5/1/07	24.5	4	4.5	3.4	20	13.6	0.5	5	34.8	31.7
BBC26U/S	1/26/06	9.16	4	1.8	1.5	30	4.4	0.2	5	15.1	13.8
BBC26U/S	2/28/06	17.2	4	3.2	2.5	30	9.1	0.4	5	25.8	23.5
BBC26U/S	4/20/06	19.2	4	3.6	2.8	30	10.3	0.4	5	28.3	25.8
BBC26U/S	2/1/07	17.4	4	3.3	2.5	30	9.2	0.4	5	26.0	23.8
BBC26U/S	2/27/07	20.2	4	3.8	2.9	30	10.9	0.4	5.1	29.5	27.0
BBC26U/S	5/1/07	21.4	4	4.0	3.0	20	11.6	0.5	5	31.0	28.3
BBC44Center	1/25/06	8.02	4	1.6	1.3	30	3.8	0.1	5.7	13.5	12.3
BBC44Center	2/28/06	9.38	4	1.8	1.5	30	4.6	0.2	5	15.4	14.1
BBC44Center	4/20/06	10.2	4	2.0	1.6	30	5.0	0.2	5	16.5	15.1
BBC44Center	2/1/07	11.5	4	2.2	1.8	30	5.8	0.2	5.6	18.3	16.7
BBC44Center	2/27/07	11.5	4	2.2	1.8	30	5.8	0.2	5	18.3	16.7
BBC44Center	5/1/07	8.55	4	1.7	1.4	20	4.1	0.2	6.6	14.2	13.0
BBC44U/S	1/25/06	4.72	4	1.0	0.8	30	2.1	0.1	8.3	8.6	7.9
BBC44U/S	2/28/06	4.17	4	0.9	0.8	30	1.8	0.1	5.1	7.8	7.1
BBC44U/S	4/20/06	4.99	4	1.0	0.9	30	2.2	0.1	6.7	9.0	8.2
BBC44U/S	1/31/07	4.94	4	1.0	0.9	30	2.2	0.1	7.5	8.9	8.2
BBC44U/S	2/26/07	3.57	4	0.7	0.7	30	1.5	0.1	5	6.8	6.2
BBC44U/S	4/30/07	4.88	19	1.0	0.9	20	2.2	0.1	24	8.9	8.1
BBC45D/S	1/25/06	4.81	4	1.0	0.8	30	2.1	0.1	6.6	8.7	8.0
BBC45D/S	2/28/06	4.27	4	0.9	0.8	30	1.8	0.1	11	7.9	7.2
BBC45D/S	4/20/06	3.73	4	0.8	0.7	30	1.6	0.1	5.7	7.1	6.4
BBC45D/S	1/31/07	4.66	4	0.9	0.8	30	2.0	0.1	5	8.5	7.8
BBC45D/S	2/26/07	3.31	4	0.7	0.6	30	1.4	0.1		6.4	5.8
BBC45D/S	4/30/07	6.29	4	1.3	1.1	20	2.9	0.1	10	11.0	10.0
BBC45U/S	1/25/06	5.65	4	1.1	1.0	30	2.5	0.1	5.4	10.0	9.2
BBC45U/S	2/28/06	4.59	4	0.9	0.8	30	2.0	0.1	6.5	8.4	7.7
BBC45U/S	4/20/06	4.66	4	0.9	0.8	30	2.0	0.1	5	8.5	7.8
BBC45U/S	1/31/07	5.56	4	1.1	1.0	30	2.5	0.1	5	9.9	9.0
BBC45U/S	2/26/07	4.55	4	0.9	0.8	30	2.0	0.1	5	8.3	7.6
BBC45U/S	4/30/07	5.87	4	1.2	1.0	20	2.7	0.1	11	10.4	9.5
BBC52	1/25/06	5.74	4	1.2	1.0	30	2.6	0.1	5.6	10.2	9.3
BBC52	2/28/06	5.65	4	1.1	1.0	30	2.5	0.1	5	10.0	9.2
BBC52	4/20/06	3.81	4	0.8	0.7	30	1.6	0.1	5	7.2	6.6
BBC52	1/31/07	5.81	4	1.2	1.0	30	2.6	0.1	5	10.3	9.4
BBC52	2/26/07	4.29	4	0.9	0.8	30	1.9	0.1	5	7.9	7.3
BBC52	4/30/07	4.65	4	0.9	0.8	20	2.0	0.1	9.9	8.5	7.8
EC3	1/24/06	28.2	4	5.2	3.8	30	15.9	0.6	5	39.2	35.8

Table T-2 continued

Site	Date	Hardness	Total Copper	Dissolved Cu acute	Dissolved Cu chronic	Total Lead	Dissolved Pb acute	Dissolved Pb chronic	Total Zinc	Dissolved Zn acute	Dissolved Zn chronic
EC3	2/28/06	28.5	4	5.2	3.9	30	16.1	0.6	8.2	39.5	36.1
EC3	4/21/06	37.9	4	6.8	5.0	30	22.1	0.9	5	50.3	45.9
EC3	1/31/07	22.6	4	4.2	3.2	30	12.4	0.5	5	32.5	29.6
EC3	2/26/07	36.7	4	6.6	4.8	30	21.4	0.8	5	48.9	44.7
EC3	4/30/07	31.3	4	5.7	4.2	20	17.9	0.7	7.4	42.8	39.1
EC4	1/24/06	10.5	4	2.0	1.7	30	5.2	0.2	6.6	17.0	15.5
EC4	2/28/06	6.84	4	1.4	1.1	30	3.2	0.1	5	11.8	10.8
EC4	4/21/06	8.02	4	1.6	1.3	30	3.8	0.1	5	13.5	12.3
EC4	1/31/07	11.1	4.7	2.1	1.7	30	5.5	0.2	10	17.8	16.2
EC4	2/26/07	9.36	4	1.8	1.5	30	4.5	0.2	5	15.4	14.0
EC4	4/30/07	22	4.4	4.1	3.1	20	12.0	0.5	17	31.7	29.0
EC61	1/24/06	4.86	4	1.0	0.9	30	2.1	0.1	5	8.8	8.1
EC61	2/28/06	4.16	4	0.9	0.7	30	1.8	0.1	5.6	7.7	7.1
EC61	4/21/06	5.97	4	1.2	1.0	30	2.7	0.1	5	10.5	9.6
EC61	1/31/07	4.18	5.4	0.9	0.8	30	1.8	0.1	5	7.8	7.1
EC61	2/26/07	3.73	4	0.8	0.7	30	1.6	0.1	5	7.1	6.4
EC61	4/30/07	6.65	4	1.3	1.1	20	3.1	0.1	5.9	11.5	10.5
SR24A	1/25/06	15.3	4	2.9	2.3	30	8.0	0.3	5	23.3	21.3
SR24A	2/28/06	15	4	2.8	2.2	30	7.8	0.3	5	22.9	20.9
SR24A	4/20/06	17	4	3.2	2.5	30	9.0	0.3	5	25.5	23.3
SR24A	2/1/07	18.3	8.1	3.4	2.7	30	9.8	0.4	9.1	27.1	24.8
SR24A	2/27/07	15.9	4	3.0	2.4	30	8.3	0.3	5	24.1	22.0
SR24A	5/1/07	17.7	4	3.3	2.6	20	9.4	0.4	5	26.4	24.1
SR24B	1/25/06	15.4	4	2.9	2.3	30	8.0	0.3	5	23.5	21.4
SR24B	2/28/06	16.6	45.6	3.1	2.4	30	8.7	0.3	13	25.0	22.8
SR24B	4/20/06	17.4	4	3.3	2.5	30	9.2	0.4	5	26.0	23.8
SR24B	2/1/07	17.3	24.9	3.3	2.5	30	9.2	0.4	7	25.9	23.6
SR24B	2/27/07	15.3	4	2.9	2.3	30	8.0	0.3	5	23.3	21.3
SR24B	5/1/07	16.6	7.4	3.1	2.4	20	8.7	0.3	5	25.0	22.8
SR24C	1/25/06	10.6	4	2.1	1.7	30	5.2	0.2	5	17.1	15.6
SR24C	2/28/06	10.7	4	2.1	1.7	30	5.3	0.2	5	17.2	15.7
SR24C	4/20/06	9.12	4	1.8	1.5	30	4.4	0.2	5	15.0	13.7
SR24C	2/1/07	11.8	4	2.3	1.8	30	5.9	0.2	5	18.7	17.1
SR24C	2/27/07	9.85	4	1.9	1.6	30	4.8	0.2	5	16.1	14.7
SR24C	5/1/07	10.6	4	2.1	1.7	20	5.2	0.2	5	17.1	15.6

Appendix U. Maximum and minimum daily temperatures

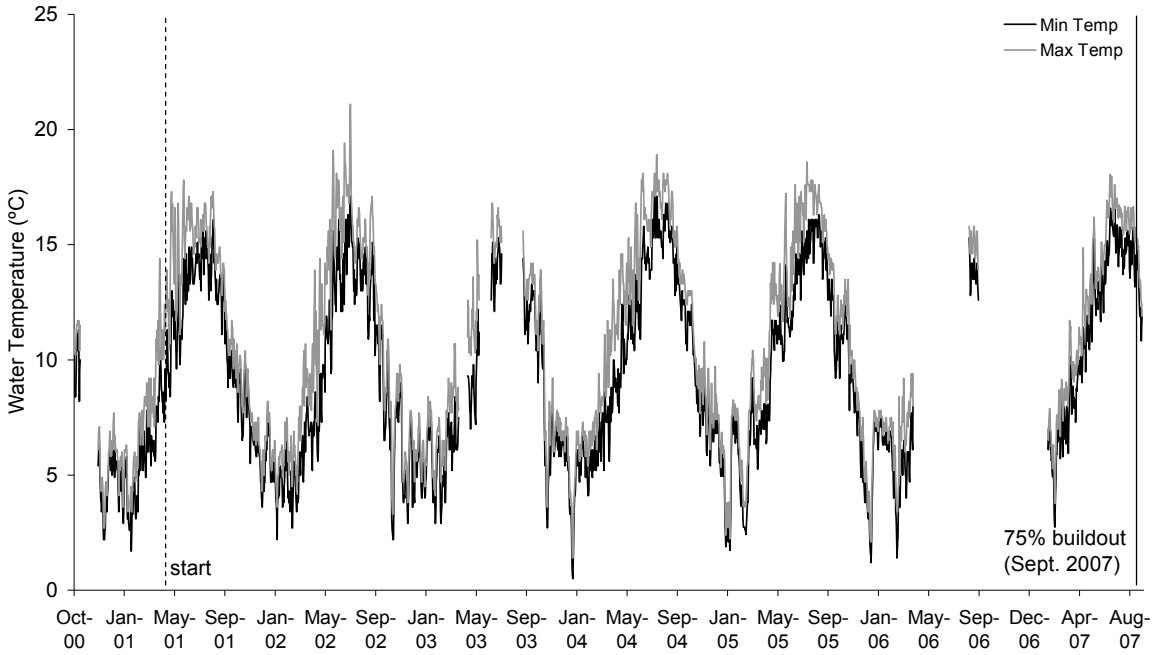

Figure U-1. The daily range of temperatures at Adair Creek gage 53A (2000-2007).
UPD construction commenced in late spring/early summer 2002 ('start') and 75% buildout was reached in September 2007.

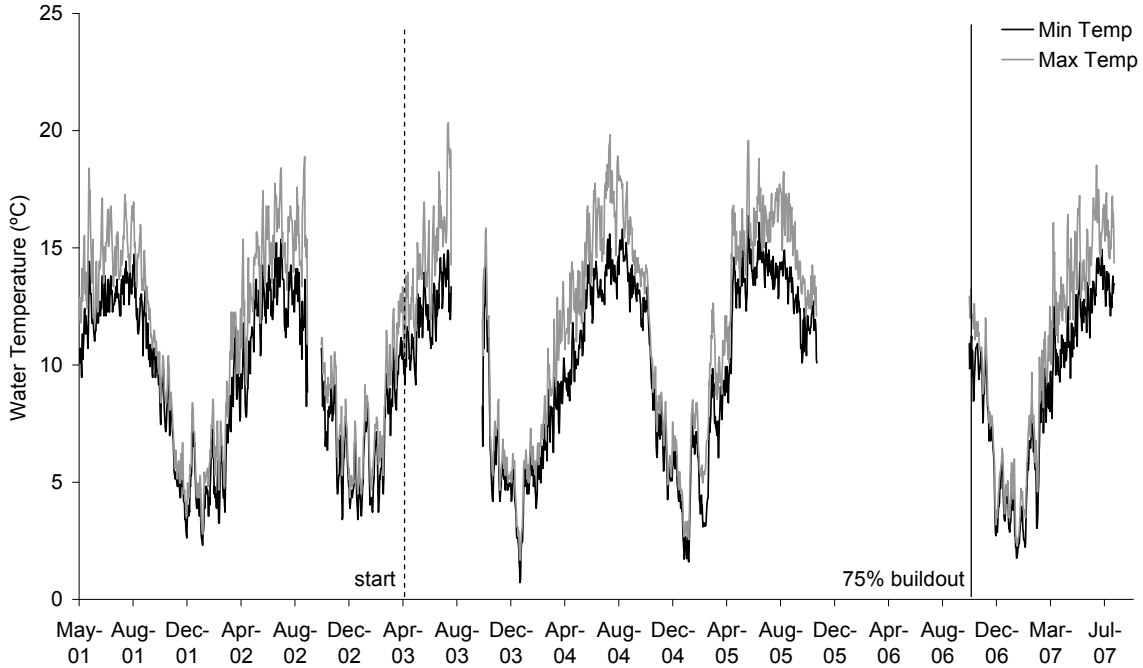

Figure U-2. The daily range of temperatures at Colin North gage 02D (2001-2007).
UPD construction commenced in late spring/early summer 2003 ('start') and 75% buildout was reached in October 2006.

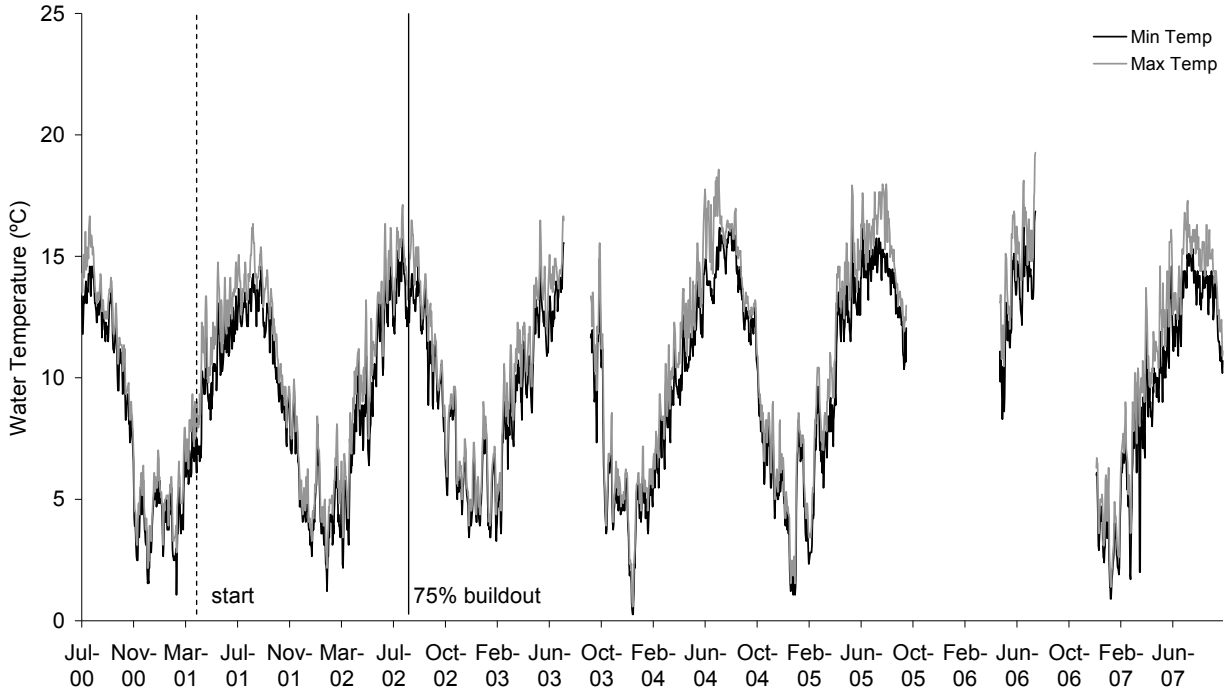

Figure U-3. The daily range of temperatures at Colin Creek South gage 02C (2000-2007).
UPD construction commenced in late spring/early summer 2001 and 75% buildout was reached in August 2002.

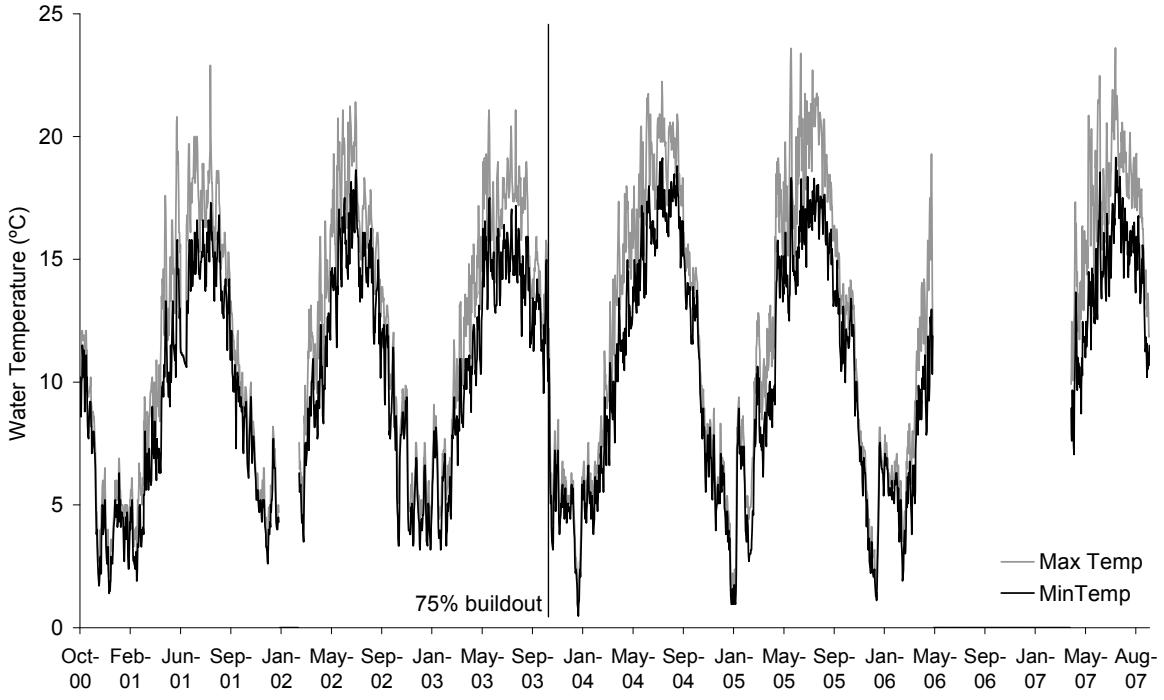

Figure U-4. The daily range of temperatures at Rutherford Creek gage 18F (2000-2007).
UPD construction commenced in late spring/early summer 1999 and 75% buildout was reached in October 2003.

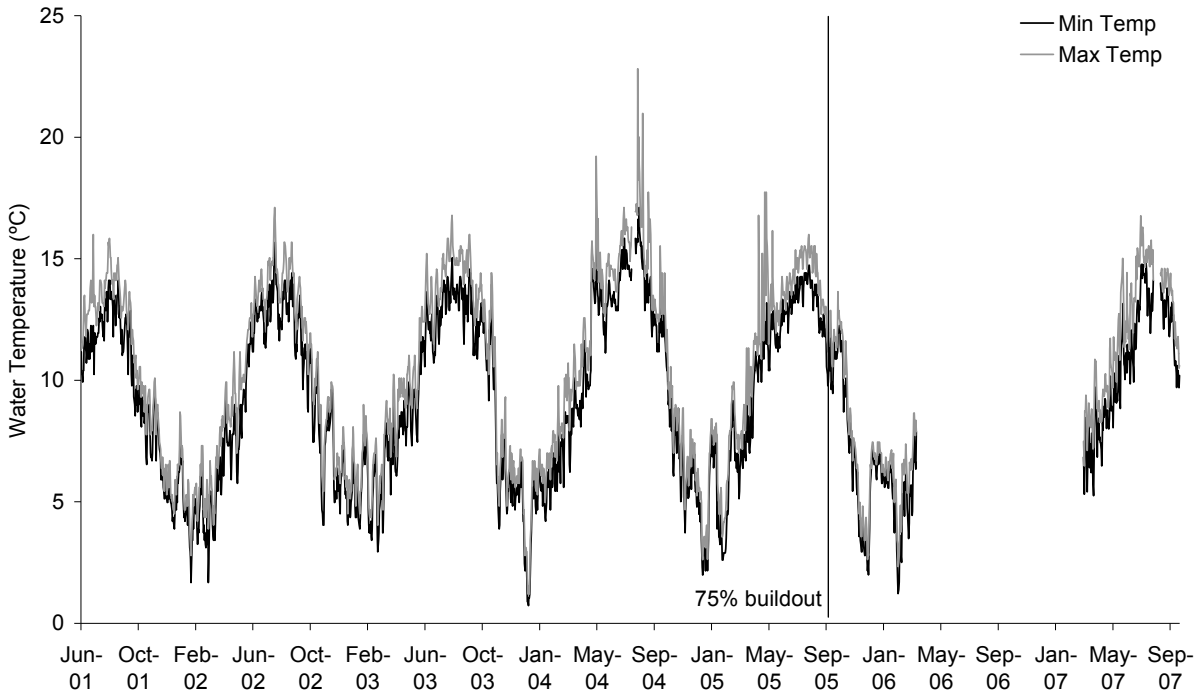

Figure U-5. The daily range of temperatures at Wallace Creek West gage 53B (2001-2007).
UPD construction commenced in late spring/early summer 2001 and 75% buildout was reached in September 2005.

Appendix V. Welcome Lake sampling schedule

Table V-1. Sampling schedule through 2007 for water quality sampling at Welcome Lake.
75% buildout was determined by Richard Lowe (Lowe 2005, 2008) and post-development is defined as after 75% subbasin buildout.

	Welcome Lake
Construction Start	**2001**
75% buildout	**June 2006**
Preconstruction	1996
	1997
	1998
	1999
	2000
During construction	2001
	2002
	2003
	2004
	2005
	2006
Post-development	**2007**

Appendix W. Additional Welcome Lake results: phosphorous, chlorophyll-a, nitrogen, Secchi, and temperature

The threshold exceedance criteria for Welcome Lake relates only to the trophic state index. This appendix presents additional Welcome Lake data that have been collected since the mid 1990s including total phosphorous, chlorophyll-a, nitrogen, Secchi transparency, and temperature.

Total phosphorus appears to have decreased during the period of 1996 through 2007 overall (Figure W-1). However, the regression correlation coefficient of 0.3642 suggests that the linear relationship (black dotted line) is not strong. Alternatively, the data could be interpreted as a step drop occurring between 1998 and 1999, followed by a period of relative stability that continues through 2007 (red lines).

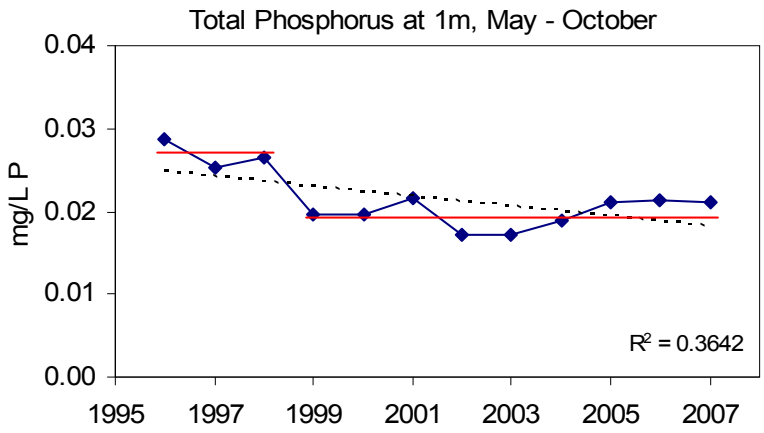

Figure W-1. Welcome Lake mean annual total phosphorous (mg/L).
Averaged from biweekly samples collected at 1-m depth from May through October, 1996 – 2007.

Chlorophyll-a concentrations have also declined from 1996 to 2007 (Figure W-2). With the exception of 1997 and 2006, chlorophyll a was higher in the period of 1996-2001 than during the period 2002-2007. In 1997, a single high chlorophyll-a value was found in May and the rest of the values were uniformly low through the season, whereas in 2006, two successive high values were measured in September that affected the seasonal average. The 2007 average chlorophyll-a concentration was consistent with the concentrations found during the 2002-2005 sample seasons. Chlorophyll-a concentrations in 2006 were not consistent (higher) with concentrations from 2002 to 2005 or 2007.

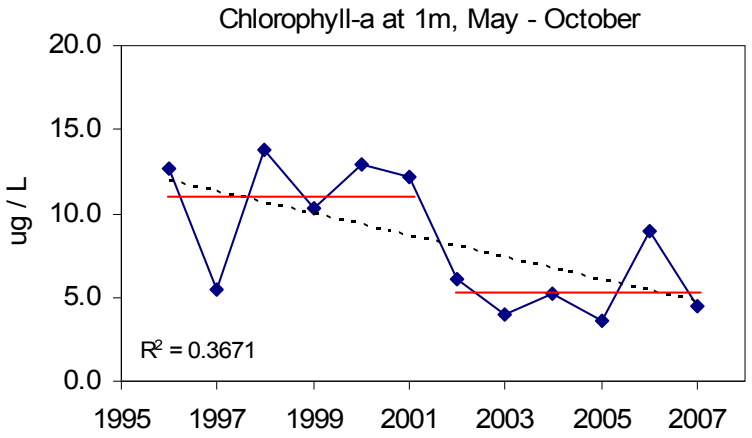

Figure W-2. Welcome Lake mean annual chlorophyll-a (µg/L).
Averaged from biweekly samples collected at 1-m depth from May through October, 1996 – 2007.

The regression correlation coefficient of 0.3671 suggests that the linear relationship (black dotted line) for chlorophyll-a is not strong. Alternatively, the data could be interpreted as a step drop occurring between 2001 and 2002 followed by a period of relative stability that continues through 2007 (red lines). However, the potential step drop observed in chlorophyll-a data in 2001 (W-2) lags three years behind the observed step drop in total phosphorous in 1998 (Figure W-1).

Total nitrogen has remained relatively constant over all years of monitoring, with no apparent trend (Figure W-3).

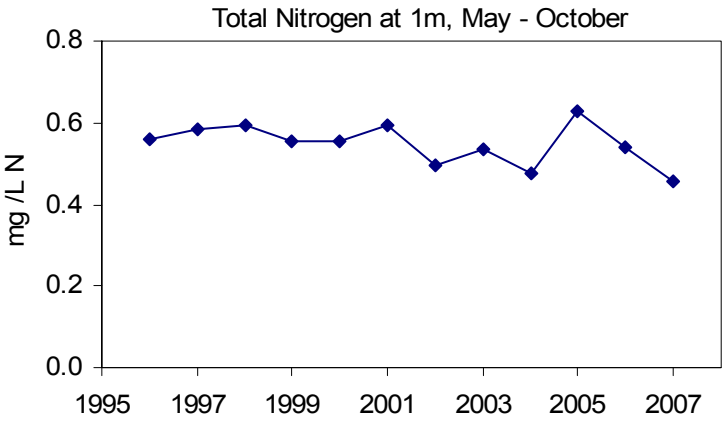

Figure W-3. Welcome Lake mean annual total nitrogen (mg/L).
Averaged from biweekly samples collected at 1-m depth from May through October, 1996 – 2007.

Secchi transparency has remained relatively constant (Figure W-4), a trend that is inconsistent with the decreases in both phosphorus and chlorophyll-a levels. This constancy suggests that algal blooms may not be the major factor affecting water clarity, and it is likely that humic acids causing the yellow-tea color of the water are an important factor in water clarity. It is also

possible that silt inputs from storms could be affecting water clarity, although most storms occur outside the period of measurement[102].

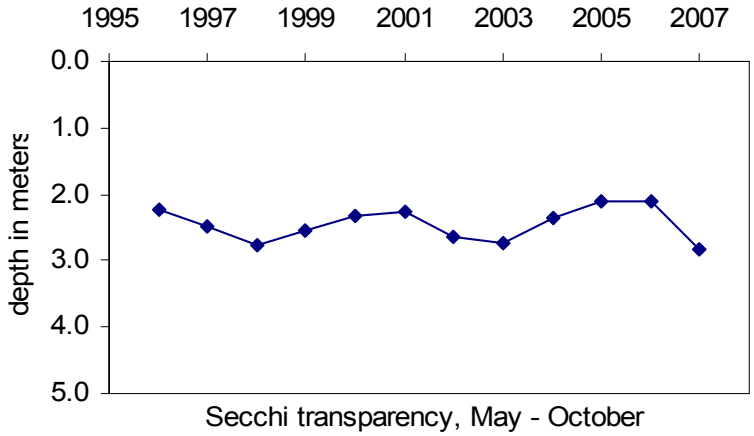

Figure W-4. Welcome Lake mean annual Secchi depth transparency (m).
Averaged from biweekly sampling over the deepest part of the lake from May through October, 1996 – 2007.

Temperature may be trending upward over time, but this trend is only weakly supported over the time period, with a regression correlation coefficient of less than 0.2 (Figure W-5). A step change does not appear to be a reasonable alternative interpretation, and more years of data will be necessary to validate a possible increase.

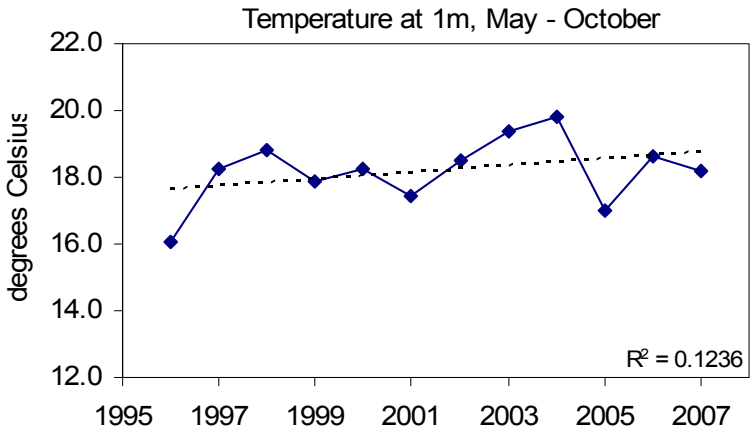

Figure W-5. Welcome Lake mean annual summer temperature (°C).
Averaged from biweekly sampling over the deepest part of the lake from May through October, 1996 – 2007.

[102] Dave Hadley, the Welcome Lake volunteer steward, has studied this possibility, using weekly Secchi data to correlate with accumulated rainfall. Unfortunately, total suspended solids data are not available to confirm his observations.

Appendix X. 2006-2007 Welcome Lake water quality data.

Table X-1. Biweekly Welcome Lake water quality data (2006-2007).
Data collected May-October. See Appendix 4.4.1.1. from the Midpoint Report for 1996-2005 data (King County 2006).

Collection Date	Secchi (m)	Temp (Deg C)	Chlor-a (µg/L)	TP (µg/L)	TN (µg/L)
8-May-06	1.9	14	9.39	14.1	515
22-May-06	3	19	3.14	16.4	461
4-Jun-06	2.1	18.8	10.5	19.8	633
18-Jun-06	2.5	18.8	5.03	14.6	562
9-Jul-06	2.3	23.2	2.66	17.8	521
30-Jul-06	2.5	22.5	2.86	13.8	518
13-Aug-06	1.8	21.5	1.98	24.4	605
27-Aug-06	1.6	21.7	16.1	15.1	440
10-Sep-06	1.5	19.8	26	12.8	502
24-Sep-06	1.5	16.3	20.6	22.5	610
8-Oct-06	2.4	15	5.65	16.5	535
22-Oct-06	2	12.8	4.16	15.8	574
6-May-07	2.5	14.5	2.36	15.2	490
21-May-07	2	15.9	9.95	21.8	554
3-Jun-07	2.2	23.2	3.02	14.1	418
17-Jun-07	3.2	17.7	2.15	14.6	433
8-Jul-07	2.5	23.8	2.25	15.9	422
29-Jul-07	1.8	22.5	4.74	14.7	429
12-Aug-07	3.2	20.4	3.71	15.4	433
26-Aug-07	3.1	20.7	6.07	16.3	433
9-Sep-07	4	19.8	4.2	16.5	400
23-Sep-07	3.5	16	5.53	15.1	402
8-Oct-07	3	13	6.53	20.7	512
21-Oct-07	3	11	3.31	19.7	538

Appendix Y. Sediment analysis sampling schedule.

Table Y-1. Sampling history for sediment metals at UPD streams.
2007 sampling events are bolded. Richard Lowe of King County DDES estimated 75% buildout within each subbasin (Lowe 2005, 2008). Construction periods are estimated from development phasing maps (KPFF Consulting Engineers 2004, Otak Incorporated 2006) and aerial photographs (1998, 2000, 2002, 2005, 2007, and 2009). Post-development is defined as after 75% subbasin buildout.

	Redmond Ridge	**Trilogy**		
	Rutherford	**Adair**	**Wallace**	**Colin South**
Construction start	1999	2002	2001	2001
75% buildout	Oct '03	Nov '06	Sept '05	Aug '02
Preconstruction		1991	1991	
	1998	1998	1998	1998
		1999	1999	1999
		2000	2000	2000
During construction	1999			
	2000			
Post-development	2005			2005
	2006			2006 – dry*
	2007			**2007**

* Colin South was visited in 2006, but the channel was dry and therefore no sample was collected.

Appendix Z. 2007 Sediment Metals Data: lab results from KCEL

Table Z-1. King County Environmental Lab (KCEL) sediment metals results.

Particle size distribution analysis also included.

PROJECT: 421195CV/CU	Locator: 0110-18F Descrip: RUTHERFORD CREEK A Sampled: 09/13/07 12:00:00 AM TimeSpan: Lab ID: L43849-1 Matrix: FRSHWTRSED % Solids: 52.8					Locator: 0132-02D Descrip: COLIN CREEK AT KC Sampled: 09/13/07 12:00:00 AM TimeSpan: Lab ID: L43849-2 Matrix: FRSHWTRSED % Solids: 23				
Parameters	Value	Qual	MDL - Dry Weight Basis	RDL	Units	Value	Qual	MDL - Dry Weight Basis	RDL	Units
COMBINED LABS										
M=CV ASTM D422(03-02-005-001)										
Clay *	3.4		0.5	1	%		<MDL	0.5	1	%
Fines *	17.8		0.5	1	%	4.2		0.5	1	%
Gravel *	18.5		0.1	1	%	64		0.1	1	%
p+0.00 *	8.5		0.1	1	%	12.3		0.1	1	%
p+1.00 *	14.7		0.1	1	%	4.4		0.1	1	%
p+10.0(equal/more than) *	2.2		0.5	1	%		<MDL	0.5	1	%
p+2.00 *	18.6		0.1	1	%	3		0.1	1	%
p+3.00 *	10.3		0.1	1	%	3.5		0.1	1	%
p+4.00 *	6.2		0.1	1	%	3.6		0.1	1	%
p+5.00 *	8.9		0.5	1	%	2.8		0.5	1	%
p+6.00 *	1.1		0.5	1	%	0.7	<RDL	0.5	1	%
p+7.00 *	4.5		0.5	1	%		<MDL	0.5	1	%
p+8.00 *		<MDL	0.5	1	%	0.7	<RDL	0.5	1	%
p+9.00 *	1.1		0.5	1	%		<MDL	0.5	1	%
p-1.00 *	7		0.1	1	%	15.4		0.1	1	%
p-2.00 *	1.3		0.1	1	%	7.3		0.1	1	%
p-2.00(less than) *	10.2		0.1	1	%	41.4		0.1	1	%
Sand *	58.3		0.1	1	%	26.6		0.1	1	%
Silt *	14.5		0.5	1	%	4.2		0.5	1	%
M=CV SM2540-G (03-01-007-002)										
Total Solids *	52.8		0.005	0.01	%	23		0.005	0.01	%
M=ES NONE										
Field Personnel	SH, JoW				none	SH, JoW				none
M=MT EPA 7471A (06-01-004-003)										
Mercury, Total, CVAA	0.049	<RDL	0.0076	0.075	mg/Kg	0.083	<RDL	0.018	0.179	mg/Kg
M=MT EPA3050B/6010B MOD(6-2-04-02)										
Arsenic, Total, ICP	6.34		0.8	3.98	mg/Kg	37.1		1.8	9.09	mg/Kg
Cadmium, Total, ICP	0.18	<RDL	0.064	0.318	mg/Kg	0.43	<RDL	0.15	0.73	mg/Kg
Copper, Total, ICP	5.51	E	0.13	0.636	mg/Kg	29.9	E	0.29	1.46	mg/Kg
Lead, Total, ICP	10.5		0.64	3.18	mg/Kg	23.6		1.5	7.3	mg/Kg
Nickel, Total, ICP	8.77	E	0.16	0.795	mg/Kg	47.8	E	0.37	1.82	mg/Kg
Silver, Total, ICP	0.3	<RDL	0.13	0.636	mg/Kg	1.66		0.29	1.46	mg/Kg
Zinc, Total, ICP	20.5	E	0.16	0.795	mg/Kg	84.8	E	0.37	1.82	mg/Kg
* Not converted to dry weight basis for this parameter										

MDL = Method detection limit; RDL = Reporting detection limit

Appendix AA. Redmond Ridge groundwater level monitoring schedule

Table AA-1. Sampling schedule through 2007 for Redmond Ridge groundwater level monitoring[103].
2007 sampling events are bolded. Richard Lowe of King County DDES estimated 75% buildout within each subbasin (Lowe 2005, 2008). Construction periods are estimated from development phasing maps (KPFF Consulting Engineers 2004, Otak Incorporated 2006) and aerial photographs (1998, 2000, 2002, 2005, 2007, and 2009). Post-development is defined as after 75% subbasin buildout.

	Redmond Ridge					
Subbasin	**Mackey**		**Rutherford**		**Evans Central**	**BBC**
OBW wells	**1, 2**	**10**	**3, 4, 7**	**11**	**6, 8**	**5**
Construction Start	**1999**		**1999**		**2000**	**2001**
75% buildout	**Sept '01**		**Oct '03**		**Oct '05**	**TBD**
Preconstruction	1996	1998	1996	1997	1996	1996
	1997		1997	1998	1997	1997
	1998		1998		1998	1998
					1999	1999
						2000
During construction	1999	1999	1999	1999	2000	2001
	2000	2000	2000	2000	2001	2002
	2001	2001	2001	2001	2002	2003
			2002	2002	2003	2004
			2003	2003	2004	2005
					2005	2006
						2007
Post-development	2002	2002	2004	2004	2006	
	2003	2003	2005	2005	**2007**	
	2004	2004	2006	2006		
	2005	2005	**2007**	**2007**		
	2006	2006				
	2007	**2007**				

[103] In addition to these 10 wells, two additional wells have been monitored. OBW-9 is in Redmond Ridge East and has been dry the entirety of the monitored period since 8/28/97. MW-8 is a shallow groundwater well in Trilogy that has been monitored since 10/31/95, but is not required.