

Trilogy and Redmond Ridge Urban Planned Development Final Monitoring Report: Water Years 2008-2010



King County

Department of Natural Resources and Parks
Water and Land Resources Division

April 2011

Executive Summary

Trilogy (formerly Blakely Ridge) and Redmond Ridge (formerly Northridge) are adjoining Urban Planned Developments (UPDs) located on approximately 2126 acres (860 hectares) in north central unincorporated King County, Washington. This final report presents the results from natural resource monitoring conducted primarily during the 2008-2010 water years (i.e., October 1, 2008 through September 30, 2010) at the UPD project site. The methods and data collected follow recommendations specified in the original Redmond Ridge and Trilogy post-development monitoring plans in addition to modifications presented in the 2007 UPD monitoring report.

A major goal of the UPD monitoring program was 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 contained 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 evaluated whether stormwater facilities were working as designed in regard to flow control and water quality objectives. Monitoring conducted by the King County Water and Land Resources Division (WLRD) has concluded and collectively the four reports that compose this document represent the final monitoring report.

This final report completes all monitoring program requirements set forth in the Development Agreements of the first two Novelty Hill Road area Urban Planned Developments: Trilogy (formerly Blakely Ridge, 1996) and Redmond Ridge (formerly Northridge, 1997). The monitoring report demonstrates that no remediation is necessary. The report also completes all financial and programmatic conditions for environmental monitoring set forth in the Blakely Ridge Urban Planned Development Agreement between King County and Port Blakely Tree Farms Limited Partnership recorded as #9601090553 and the First Amendment to said Agreement recorded as #9707291427, and the Northridge Urban Planned Development and Fully Contained Community Development Agreement between King County and the Quadrant Corporation recorded as #9702181008.

Monitoring initiation and duration of specified parameters is often linked to 75 percent subbasin buildout. At the end of the 2010 water year, eight out of nine UPD subbasins had reached this threshold; the exception was the Big Bear Creek (BBC) subbasin, at only 25 percent buildout.

The Trilogy and Redmond Ridge monitoring plans identified specific threshold exceedance criteria to evaluate the effectiveness of protective actions. Exceedance of one or more thresholds would trigger an investigation into the cause of the exceedance and required: (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 2010 water year, no corrective actions are recommended.

Outside of a few examples of threshold exceedances that are documented in this report but could not conclusively be linked to UPD development, measurable negative impacts to monitored

receiving streams or on-site wetlands have not been demonstrated during the 12-year UPD monitoring program. These results suggest that the 200-ft buffer averaging of buffers around streams and wetlands in addition to stormwater facilities (including retention ponds, infiltration ponds, conveyance systems, and water quality treatments) appear to have effectively mitigated the project impacts to the extent they can be measured at this time. No remediation of the constructed facilities is required at this time and the monitoring funds set aside for that purpose have been returned to the developer. In summary, the UPD monitoring demonstrates to the extent possible that the management actions required for both Redmond Ridge and Trilogy appear to have provided the environmental protections intended for these UPDs. This report is the final monitoring report and concludes WLRD's monitoring obligations for the Redmond Ridge and Trilogy UPDs.

In the following subsections, the monitoring procedures and results from the different elements of the 2008-10 monitoring period are summarized for all representative monitoring objectives.

Precipitation

Precipitation monitoring was conducted to provide supporting data for the interpretation of results from other monitoring activities (e.g., wetland and stream hydrology evaluation). Water years 2008 and 2009 had total precipitations of 43.31 inches (110.0 cm) and 40.45 inches (102.7 cm), respectively, which was slightly below the 1989-2010 annual average of 44.99 inches (114.3 cm). At 51.72 inches (131.4 cm), water year 2010 was the sixth wettest year between 1989 and 2010. No threshold exceedance criteria were associated with precipitation, and therefore no corrective actions are recommended.

Macroinvertebrates

Benthic macroinvertebrate monitoring based on the benthic index of biotic integrity (BIBI) was conducted to assess impacts to fisheries' food supplies and aquatic habitat. 2008 to 2010 BIBI scores at the seven monitored creeks were generally within the range of predevelopment conditions, although there were two exceptions that violated threshold exceedance criteria. The low BIBI score at Colin Creek North in 2008 (17.3) rebounded to predevelopment levels in 2009 and 2010. The low BIBI score at Adair Creek in 2010 (14) was attributed to a beaver dam blowout that scoured the channel and was not likely linked to UPD development. Wallace Creek BIBI scores were low relative to predevelopment conditions in 2006, 2008, and 2010, but did not exceed threshold exceedance criteria. These low scores may be associated with increased deposition from the unstable slopes near a large debris slide that took place in the upper reaches of Wallace Creek in 2005. Changed conditions could not be linked to UPD development, and as a result, no corrective actions are recommended.

Amphibians

Amphibian breeding surveys were conducted in 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 and mortality. The species richness observed at each sampling location in the final year of monitoring (2008, 2009, or 2010) was the same as at least one year of predevelopment species richness across all wetland locations. In general, egg mass abundances of northwestern salamanders and northern red-legged frogs between 2008 and 2010 were within the range of preconstruction abundances. In the case of northwestern salamanders at BBC-45d/s

and BBC-52 and northern red-legged frogs at BBC-52, the 2008-2010 egg mass abundances greatly exceeded preconstruction abundances. Pacific treefrogs were monitored, but no threshold exceedance thresholds were associated with this species. However, Pacific treefrog egg mass abundance was less than preconstruction abundances at BBC-52 in 2009 and 2010 and at SR-24c since 2002. BBC-45d/s and BBC-45u/s had egg mortality increases by more than 20 percent compared to preconstruction data for northwestern salamanders (BBC-45d/s: 2007, 2008, 2009, and 2010; BBC-45u/s: 2009). However, unusually high egg mass mortality was observed at BBC-45d/s even before UPD construction began. Therefore, no mortality can be directly linked to UPD development and no corrective actions are recommended.

Fish

Fish abundance and species richness was monitored annually or biennially using electrofishing surveys at Adair (2009, 2010), Colin South (2008, 2010), and Evans East (2008, 2010) Creeks. Cutthroat trout were collected during all sampling dates at all three streams. Coho were collected at Adair Creek both years and at Colin Creek South in 2008. Rainbow trout were collected at Colin Creek South in 2008. In addition, two non-native sunfish species were collected in Evans Creek East: one green sunfish in 2008 and five pumpkinseed in 2010. No fish species present before UPD development disappeared in any sampling season (the threshold exceedance criteria), and no corrective actions are recommended.

Wetland Vegetation

Wetland vegetation was monitored in even-numbered years starting in 2000 at BBC-52 to detect any changes in the wetland plant communities. There was no difference in species richness in forest, shrub, or herbaceous quadrats between predevelopment (2000-2004) and construction (2006-2010) periods. In addition, non-native invasive species (holly, evergreen blackberry, and European mountain ash) do not seem to be noticeably expanding or increasing in cover except reed canarygrass, which is expanding into the open waters in the south of the wetland. Reed canarygrass was present prior to UPD construction and its relatively slow spread does not seem to be linked to UPD development. Therefore, no corrective actions are recommended.

Stream Channel Stability

Stream cross-sections were measured at established transect stations to identify areas of erosion or channel instability and to track changes in channel shape over time. Threshold exceedance criteria related to bed erosion or deposition were exceeded in all streams except Colin Creek North. However, some of these exceedances were isolated and did not persist throughout the stream survey reach; other exceedances were attributed to natural channel processes. Interpretation of other exceedances was complicated by placement of the cross-sections near culverts or non-UPD development and isolated non-UPD associated high flow events or debris slides. In addition, at over half of the stream cross-sections, there were no obvious progressive trends of erosion and/or accretion when current and previous survey results were evaluated on a continuum. UPD related changes in channel stability do not appear to be a significant concern in the seven monitored creeks and 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) were effectively limiting pollutants in

receiving surface waters. Water quality sampling followed one of three regimes: (1) annual sampling three times between January and April at 13 locations in 8 wetlands (BBC-26, BBC-44, BBC-45, BBC-52, EC-3, EC-4, EC-61, and SR-24) and 7 locations in 5 streams (Adair, Colin South, Evans Central, Wallace, and Rutherford Creeks); (2) continuous temperature monitoring in 5 streams (Adair, Evans Central, Wallace West, Colin South, and Colin North Creeks); or (3) summer/fall wetland sampling in 2 wetlands (BBC-45 and BBC-52).

January through April Sampling

The January to April measurements revealed that, although specific conductivity within the Big Bear Creek, Wallace Creek, Evans Creek Central, and part of the Colin Creek South subbasins remained within the same range between 2002 and 2010, the other subbasins exhibited some increases in conductivity relative to predevelopment conditions. No subbasins showed any decreases in conductivity. The Colin Creek North and Rutherford Creek subbasins showed the strongest increases. Two locations in wetland BBC-26 increased from less than 55 $\mu\text{S}/\text{cm}$ in 2002 to greater than 75 $\mu\text{S}/\text{cm}$ in 2009; wetland EC-3 measured less than 60 $\mu\text{S}/\text{cm}$ prior to 2004 to over 80 by 2007. Temperatures for all streams and wetlands maintained an average of between 6 and 9°C at most sampling sites except BBC-26u/s, which had an average of 10.3°C. Across the monitored streams and wetlands, 2008-2010 pH measurements were comparable with those in 2002-2004 (some elevated pH measurements were observed in 2005 and 2006). Hardness measurements at wetland EC-3 have doubled since 1991; increases and decreases at other sites have been comparatively small in magnitude. Alkalinity measurements have been made less frequently than hardness measurements, and most changes observed may represent natural year-to-year variability. As a result of the sampling design, the natural predevelopment variability in most field parameters was not well understood. Nevertheless, the increasing trends in conductivity across several wetland and stream locations may be linked to increased urbanization associated with UPD development. However, no state water quality standards are associated with conductivity, and no corrective actions are recommended.

Continuous Sampling

Continuous temperature monitoring suggested that stream temperatures followed 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 were occasionally above the 17.5°C water quality criteria, likely as a result of their proximity to upstream open water wetlands and were not linked to UPD development. No corrective actions are recommended.

Summer/fall Wetland Sampling

Summer/fall wetland sampling for nutrient, herbicide, and conventional water quality parameters at BBC-45 d/s and BBC-52 in 2009 and 2010 indicates that there have not been changes compared to 1991 and 1992 predevelopment data. No corrective actions are recommended.

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 was focused on whether UPD development was affecting the trophic state of Welcome Lake. The 2008 trophic state index (TSI) value (45.9) was below the preconstruction range of 46.5

(2000) to 52.0 (1996); however, the 2009 TSI value (48.6) jumped to the middle of the preconstruction range. However, there have been no values exceeding the high end of the preconstruction range, and therefore no corrective actions are recommended.

Groundwater Hydrology

The objective of groundwater hydrology monitoring was to ensure that groundwater recharge was 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 12 observation wells and will continue until October 2011, 8 years after Redmond Ridge 75 percent buildout. 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 2 to 7 months. Trilogy groundwater-level monitoring was conducted at 20 shallow wells from April 2004 to September 2006 by AESI and from December 2009 through January 2011 by WLRD. The 2010 water year data had similar trends to the 2004-2006 dataset and the groundwater levels responded to precipitation like at Redmond Ridge. The threshold criteria were not exceeded, and no corrective actions are recommended.

Groundwater Quality

Groundwater quality monitoring was required in the Redmond Ridge monitoring plan to verify that there was no degradation from infiltration facilities of groundwater approaching sensitive receiving bodies (i.e., streams and wetlands) or wells. Fall 2010 data for fecal coliform bacteria were below detection limits and nitrate-nitrite nitrogen fall within predevelopment levels observed at regional wells within the same aquifer. The threshold criteria were not exceeded, and no corrective actions are recommended.

Hydrology

Stream and wetland hydrologic monitoring was conducted with the intent of ensuring that the Trilogy and Redmond Ridge UPDs did not significantly disrupt the pre-development hydrology. A complex system of storm water controls was built into the developments to maintain the hydrologic response of the streams and wetlands near their predevelopment condition. The overall goal of the hydrologic monitoring was to determine if there were unexpected changes in the hydrology of streams and wetlands as a result of UPD construction and full build out. The hydrologic monitoring methods followed recommendations specified in the original Redmond Ridge and Trilogy post-development monitoring plans. A data-based approach comparing pre- and post-development metrics was used in the assessment. The justification for this assessment approach is described in the hydrology report.

Stream Hydrology

The assessment of stream hydrology relied on evaluation of annual peak flow, flow flashiness metrics, and measures of summer drought and low flow at seven UPD streams. Apparent, but inconclusive trends potentially associated with UPD development were noted in Colin Creek North and Adair Creek. However, it does not appear that significant changes have occurred in the gaged stream channel cross sections downstream of these gages or that shifts have occurred in the stream biological communities sampled in the vicinity of these gages that are consistent

with the suggested trends. No corrective actions are recommended for the stream hydrology component of the monitoring plan.

Wetland Hydrology

The assessment of wetland hydrology relied on evaluation of June 30 water level, spring/summer median water level, winter median water level, and Wetland Level Fluctuation (WLF) in twelve UPD wetlands. In general, the hydrology of several of the wetlands appeared to have changed over time, although the variety of sampling methods used (and the lack of any pre-development data at two wetlands) made it difficult to determine if these changes were related to UPD development. In many cases, outlet modifications due to alteration through road berm changes and beaver activity were likely causes of observed changes in water levels. It is not possible to connect any of the apparent changes to biological effects because the best documented biological connection with wetland water levels is with wetland plant species richness – which was monitored in only one UPD wetland (BBC-52) that did not ultimately undergo full (> 75% buildout) development during the monitoring program. The next strongest documented link between wetland water levels and biology is with amphibian species richness. The only notable change in amphibians that coincided with a relatively large shift in WLF following construction was in wetland SR-24C. In this wetland a decline in Pacific treefrog egg mass abundance coincided with 75% buildout, but a decline in egg mass abundance was also noted in the relatively undeveloped wetland BBC-52 that did not show any shift in WLFs during the same time period. Based on the available data, there does not appear to be compelling evidence that the development of the UPDs resulted changes in wetland water levels that resulted in biological changes. Other wetlands with apparent increases in WLFs (e.g., BBC-45A and SR-24A) were not monitored for biological changes.

No corrective actions are recommended for the wetland hydrology component of the monitoring plan. However, the available data suggest that the mean wetland levels in BBC-26 may have increased between 2005 and 2010 even though WLFs remained low post-development. There is no obvious link to rising BBC-26 water levels and UPD development, and observed beaver activity near the wetland outlet may be responsible for the increased wetland height. No roads or houses are threatened at current wetland levels and future monitoring is beyond the scope of the UPD monitoring project.

Facility Water Level

Stormwater facility water level monitoring was required by both the Trilogy and Redmond Ridge monitoring plans to verify facility performance. During the period October 2007 through December 2010, five facilities were monitored with crest-stage recorders and four facilities were monitored with continuous water level recorders. Flow was also monitored in the two bypass pipelines that divert stormwater from Adair Creek and Wallace Creek.

Crest-stage Gages

None of the stormwater facilities with crest-stage gages have gone into overflow during the monitoring period and no corrective actions are recommended.

Continuous Gages

Continuous monitoring of Redmond Ridge ponds ECW3-1, ECW2-1 and NWD1-A indicated the ponds were working as designed with respect to control of stormwater discharge. Continuous monitoring at Redmond Ridge pond ECW1B1 indicated that the peak release rates exceeded the design targets for the 2-year return storm during periods of prolonged rain, but peak flows rates were similar to the predevelopment condition and EC-3 wetland fluctuations downstream of this facility were similar to an undeveloped basin. No corrective actions are recommended for any of these facilities.

Bypass Pipelines

The bypass pipeline system for Wallace Creek was functioning correctly. The bypass pipeline system for Adair Creek was functioning to reduce peak flows but may not divert enough stormwater to maintain the flow durations at a predevelopment condition. No loss of biological stream function was observed in Adair Creek, and therefore no corrective actions are advised.

Facility Water Quality

During 2008, five stormwater facilities in the Trilogy and Redmond Ridge Urban Planned Developments (UPDs) were monitored for water quality during storms. The objective of the study was to quantify removal efficiencies of trace metals, nutrients, suspended solids, and fecal coliform bacteria. Performance standards for stormwater facilities in the UPDs were set forth in the Trilogy and Redmond Ridge monitoring plans. Methods for measuring facility performance differed by development and required differing numbers of storms, differing methods of sampling and analysis, and differing reporting requirements. For this reason, results were reported in separate sections by UPD. In general for both developments, it appeared that water quality improved during the time stormwater was being treated in the stormwater facilities. Many of the concentrations of stormwater entering and leaving the facilities were extremely low, some even below detection limits. At concentrations within the measurement error for a given parameter, it was not possible to say if concentrations or loadings increased or decreased, and by extension, if reduction targets were met. Therefore, no corrective actions are recommended.

Acknowledgements

The background work for this project has involved numerous consultants, King County employees, and University of Washington staff and students whose contributions date back to the early 1990s. In particular, much of the important planning and implementation of this study were undertaken by Kari Osterhaug, Liz Ritzenthaler, Heidi Wachter, and Karen Comings and project financing and budgeting has been overseen by Kerry Thrasher. Numerous interns and staff have helped with data collection and organization over the years, but we would particularly like to thank those who provided help during the 2008-2010 water years including Lake Stewardship volunteer Dave Hadley; AESI employees Jenny Saltonstall and Homer Welborn; and King County employees Judy Blanco, Bob Brenner, Audrey Djunaedi, Eric Ferguson, Chris Gregersen, Stephanie Hess, Kollin Higgins, Chris Knutson, Beth leDoux, Carolyn Shores, and Jennifer Vanderhoof in addition to the Field Services Unit of the King County Environmental Laboratory. We thank Richard Lowe, Lisa Lee, and Bob Kelley for their ongoing advice, guidance, and historical context in implementing the monitoring plans. Finally, we thank Tom Ventur for his keen eye and attention to detail during final editing of this document, Laurel Preston for her assistance with graphics, and Kate O’Laughlin, Jim Simmonds, Scott Stolnack and Jennifer Vanderhoof for their internal reviews.

Introduction to Final Report

Trilogy (formerly Blakely Ridge) and Redmond Ridge (formerly Northridge) are adjoining Urban Planned Developments (UPDs) located on approximately 2,560 acres (1,035 hectares) in north-central unincorporated King County, Washington. Permit-required natural resources and facilities monitoring has been conducted primarily by the King County Water and Land Resources Division (WLRD) since 1998 and concluded in early 2011. The four reports compiled within this document present the results from monitoring conducted primarily during the 2008-2010 water years (i.e., October 1, 2008 through September 30, 2010) at the UPD project site and collectively they represent the final monitoring report. This final report completes all monitoring program requirements set forth in the Development Agreements of the first two Novelty Hill Road area Urban Planned Developments: Trilogy (formerly Blakely Ridge, 1996) and Redmond Ridge (formerly Northridge, 1997). The monitoring report also demonstrates that no remediation is necessary. The methods and data collected follow recommendations specified in the original Redmond Ridge and Trilogy post-development monitoring plans in addition to modifications presented in the 2007 UPD monitoring report.

Collectively the 2007 UPD report and this report satisfy all financial and programmatic conditions for environmental monitoring set forth in the Blakely Ridge Urban Planned Development Agreement between King County and Port Blakely Tree Farms Limited Partnership recorded as #9601090553 and the First Amendment to said Agreement recorded as #9707291427, and the Northridge Urban Planned Development and Fully Contained Community Development Agreement between King County and the Quadrant Corporation recorded as #9702181008.

The four reports will be presented in the following order and each will include the content specified below:

1. “Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Biological, Physical, and Chemical Monitoring for Water Years 2008-2010” summarizes the natural resource monitoring results of UPD wetlands, lakes, streams, and groundwater surveys including macroinvertebrates, amphibians, fish, wetland vegetation, stream channel stability, water quality, Welcome Lake trophic state, groundwater hydrology, and groundwater quality.
2. “Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Final Stream and Wetland Hydrologic Monitoring Assessment” presents the analysis from stream and wetland gage monitoring.
3. “Trilogy and Redmond Ridge Urban Planned Development (UPD) Final Facilities Monitoring Report” presents data from both continuous and crest-stage gage monitoring of stormwater ponds.
4. “2008 Wet Weather Stormwater Facility Water Quality Monitoring at the Trilogy and Redmond Ridge Urban Planned Developments (UPDs)” presents the water quality results from stormwater performance monitoring from 2008.

Each report evaluates the appropriate threshold criteria identified in the Trilogy and Redmond Ridge monitoring plans to determine whether there were significant changes to the natural resources (e.g., streams, wetlands, fisheries, and groundwater) as a result of UPD development and to evaluate whether stormwater facilities were working as designed in regard to flow control and water quality objectives. Through the 2010 water year, no corrective actions are recommended.

Citations

Please cite each portion of this document individually:

King County. 2011. Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Biological, Physical, and Chemical Monitoring for Water Years 2008-2010. Prepared by Jo Wilhelm and Sally Abella. Water and Land Resources Division. Seattle, Washington.

King County. 2011. Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Final Stream and Wetland Hydrologic Monitoring Assessment. Prepared by Curtis DeGasperi. Water and Land Resources Division, Seattle, Washington.

King County. 2011. Trilogy and Redmond Ridge Urban Planned Development (UPD) Final Facilities Monitoring Report. Prepared by David Funke. Water and Land Resources Division, Seattle, Washington.

King County. 2011. 2008 Wet Weather Stormwater Facility Water Quality Monitoring at the Trilogy and Redmond Ridge Urban Planned Developments (UPDs). Prepared by Raymond Timm. Water and Land Resources Division, Seattle, Washington.

Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Biological, Physical, and Chemical Monitoring for Water Years 2008-2010

Prepared by: Jo Wilhelm and Sally Abella. King County Department of Natural Resources and Parks, Water and Land Resources Division. April 2011.



King County

Department of
Natural Resources and Parks

Water and Land Resources Division

201 South Jackson Street, Suite 600
Seattle, WA 98104

Table of Contents

1.0	Introduction	1
1.1	Monitoring Program Goals	4
1.2	Threshold Exceedance Criteria	5
2.0	Construction Overview: Water Years 2008-2010.....	5
2.1	Trilogy	5
2.2	Redmond Ridge	5
2.3	Redmond Ridge East	7
3.0	Natural Resources Monitoring Activity.....	7
3.1	Precipitation	12
3.2	Macroinvertebrates	15
3.3	Amphibians	20
3.4	Fish	26
3.5	Wetland Vegetation	32
3.6	Stream Channel Stability (Stream Cross-Sections).....	38
3.7	Water Quality	51
3.8	Welcome Lake Trophic State.....	70
3.9	Groundwater Hydrology	73
3.10	Groundwater Quality	80
4.0	UPD Monitoring Program Conclusion	82
4.1	UPD Stream Monitoring–Duration Modification	83
4.2	UPD Wetland Monitoring: BBC-45 and BBC-52.....	83
4.3	UPD Groundwater Monitoring	84
4.4	UPD Facilities Monitoring.....	86
5.0	References	89
6.0	Appendices.....	97
	Appendix A. Names, numbers, and drainage basin for streams draining the UPDs	99
	Appendix B. Precipitation data for water years 2008-2010	100
	Appendix C. Levels of biological condition for BIBI scores	104
	Appendix D. BBC-52 wetland vegetation strata.....	105
	Appendix E. BBC-52 lumped taxa	106
	Appendix F. BBC-52 vegetation list.....	108
	Appendix G. BBC-52 invasive species locations	111
	Appendix H. Dissolved oxygen results	112
	Appendix I. Turbidity results.....	116

Appendix J. Metals data	119
Appendix K. Summer/fall wetland water quality data.....	121
Appendix L. Welcome Lake phosphorus, chlorophyll-a, nitrogen, Secchi, and temperature	122
Appendix M. Trilogy groundwater levels compared to precipitation.....	125
Appendix N. Trilogy groundwater levels (water years 1992, 2005, 2006, and 2010).....	126
Appendix O. Regional groundwater quality data	129

Tables

Table 1. Development summary by UPD subbasin.	4
Table 2. 2008-2010 water year monitoring activities.	11
Table 3. BIBI Scores for UPD Creeks.	18
Table 4. Macroinvertebrate quantities for each replicate for UPD creeks.	19
Table 5. Amphibian egg mass abundance from 2000 to 2010.	24
Table 6. Amphibian egg mass mortality.	25
Table 7. Summary by species and pass for 2000 and 2006-2010 fish sampling.	30
Table 8. Species collected during electrofishing sampling dates on UPD creeks.	31
Table 9. Wetland vegetation strata and quadrat size.....	34
Table 10. Large cover class changes (> 2) at BBC-52 quadrats across all years.	35
Table 11. BBC-52 invasive species.	37
Table 12. Stream cross-section annual thalweg depth measurements.	41
Table 13. Threshold exceedance criteria for stream cross-section locations.	51
Table 14. 2008-2010 stream pH measurements below state criteria of 6.5.	63
Table 15. Stream temperature exceedances of state criteria 2008-2010.	68
Table 16. Water quality data for BBC-45 and BBC-52 wetlands.	69
Table 17. 2010 groundwater quality results.	81
Table 18. Summary of UPD monitoring components: status, future proposals, and rationales...82	
Table A-1. UPD Stream names, drainage basins, and stream numbers.	99
Table B-1. Daily and monthly precipitation totals in inches for water year 2008.....	100
Table B-2. Daily and monthly precipitation totals in inches for water year 2009.....	101
Table B-3. Daily and monthly precipitation totals in inches for water year 2010.....	102
Table B-4. Summary of monthly precipitation totals in inches by water year.	103
Table C-1. BIBI biological condition categories.	104
Table D-1. BBC-52 plot vegetation strata by year.....	105
Table E-1. BBC-52 lumped taxa.....	106

Table F-1. BBC-52 vegetation list.	108
Table H-1. Stream dissolved oxygen levels below 6.5 mg/L, 2002-2010.	114
Table I-2. Turbidity observations exceeding 10 NTU.	118
Table J-1. Metal concentrations relative to state and federal toxic criteria (2009 and 2010). ...	120
Table K-1. Summer/fall wetland water quality data.	121
Table O-1. Regional groundwater quality data: nitrogen and coliform bacteria.	129

Figures

Figure 1. Location of the Trilogy and Redmond Ridge UPDs.	1
Figure 2. UPD subbasins.	3
Figure 3. 2008-2010 Redmond Ridge and Trilogy UPD construction activities.	6
Figure 4. Sampling locations for natural resource monitoring parameters.	9
Figure 5. Location of five UPD-related precipitation gages.	13
Figure 6. Cumulative annual precipitation for water years 1989 through 2010.	15
Figure 7. Location of seven UPD benthic macroinvertebrate monitoring stations.	16
Figure 8. Location of amphibian breeding surveys.	21
Figure 9. Species composition of amphibian egg masses at various UPD wetland sites.	23
Figure 10. Fish sampling locations.	28
Figure 11. BBC-52 vegetation sampling transect and quadrat set up.	33
Figure 12. Species per strata for baseline and construction periods at BBC-52.	36
Figure 13. Frequency of invasive species observed in BBC-52.	37
Figure 14. Approximate location of stream cross-section measurements.	39
Figure 14. Adair Creek stream cross-sections.	43
Figure 16. Colin Creek North stream cross-sections.	44
Figure 17. Colin Creek South stream cross-sections.	45
Figure 18. Evans Creek Central stream cross-sections.	46
Figure 19. Mackey Creek stream cross-sections.	47
Figure 20. Rutherford Creek stream cross-sections.	48
Figure 21. Wallace Creek stream cross-sections.	49
Figure 22. Comparison of same year cross-section measurements at Mackey Creek.	50
Figure 23. Location of 20 January through April water quality sampling stations.	53
Figure 24. Average annual specific conductivity (1991, 2002-2010).	57
Figure 25. Average annual temperature (1991, 2002-2010).	59
Figure 26. Average annual pH (1991, 2002-2010).	61

Figure 27. Hardness measurements for UPD water quality sites (1991, 2006-2010).....	64
Figure 28. Alkalinity measurements for UPD water quality sites (2006-2007).....	65
Figure 29. Location of five continuous temperature gage locations.....	67
Figure 30. Welcome Lake average TSI scores (1996-2007).....	72
Figure 31. Welcome Lake individual parameter TSI scores (1996-2009).....	73
Figure 32. Groundwater well monitoring locations.....	75
Figure 33. Precipitation and groundwater level data for MW-4B (2004-2006 and 2010).....	77
Figure 34. Groundwater level data for MW-4A (1992, 2005, 2006, 2010).	78
Figure 35. Groundwater level data for MW-6A, -6B, and -7 (1992, 2005, 2006, 2010).....	78
Figure 36. Groundwater level data for MW-1 (1992, 2005, 2006, 2010).....	79
Figure G-1. BBC-52 invasive species locations.	111
Figure H-1. Average dissolved oxygen (1991, 2002-2010).....	112
Figure H-2. The south weir.....	115
Figure I-1. Average annual turbidity (1991, 2002-2010).....	116
Figure L-1. Welcome Lake mean annual total phosphorus (mg/L).....	122
Figure L-2. Welcome Lake mean annual chlorophyll-a (µg/L).	123
Figure L-3. Welcome Lake mean annual total nitrogen (mg/L).....	123
Figure L-4. Welcome Lake mean annual Secchi depth transparency (m).	124
Figure L-5. Welcome Lake mean annual summer temperature (°C).....	124
Figure M-1. Monthly precipitation totals and Trilogy groundwater levels by water year (2004-2006 and 2010).	125
Figure N-1. Trilogy groundwater levels by water year.....	126

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 2126 acres (860 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.

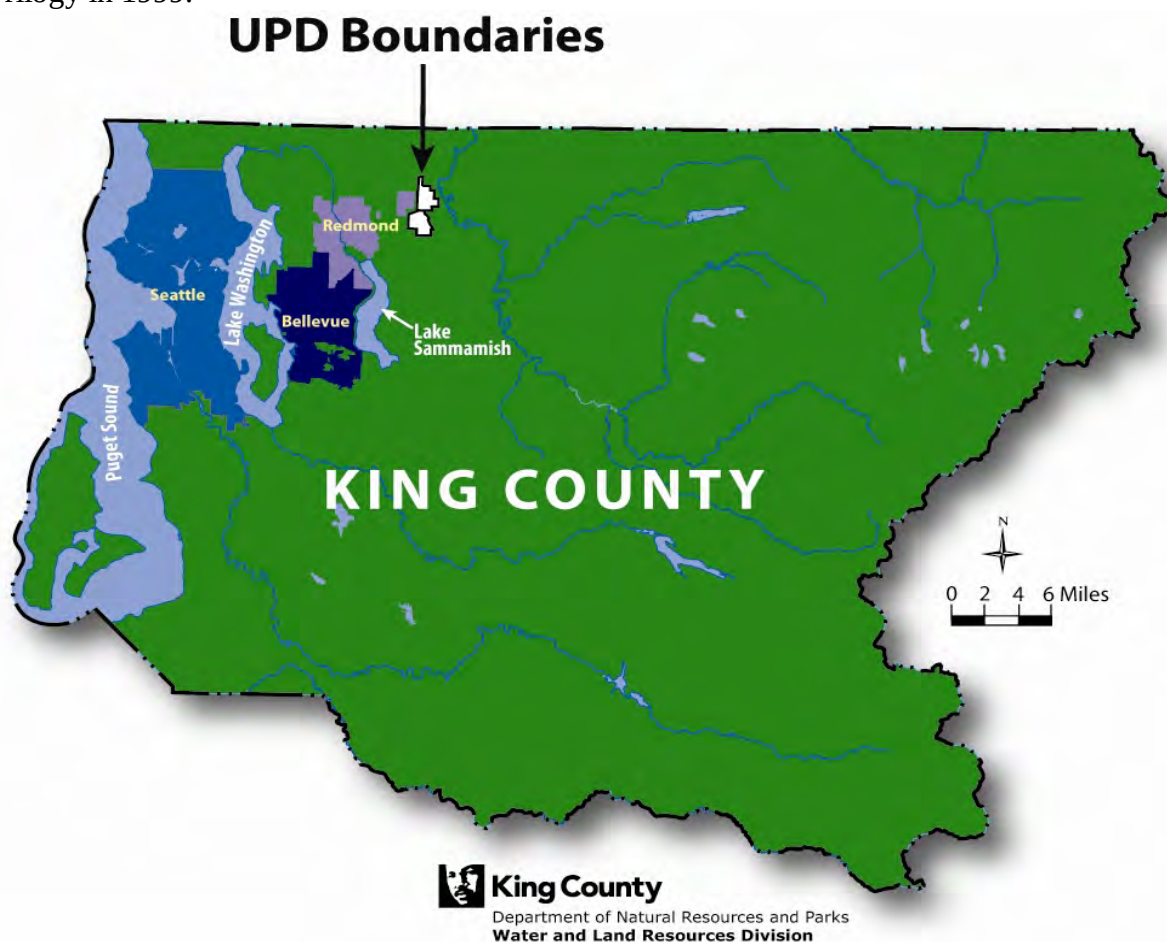


Figure 1. Location of the Trilogy and Redmond Ridge UPDs.

The project area contains over 126 wetlands draining to 8 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, both projects have adhered to a master drainage plan (Northwest Engineering Company 1995, Hugh G. Goldsmith and Associates 1996) calling for retention of 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 1,100 acres (445 hectares) have been preserved as natural resource buffers, and 58 stormwater ponds have been constructed.

The 2007 Annual Report (King County 2010), 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 2007. This report presents a brief overview of the 2008 to 2010 water years (i.e., October 1, 2008 through September 30, 2010) construction activities (Section 2) and the results from natural resource monitoring (Section 3) including recommendations for corrective actions where appropriate. Results from wetland and stream hydrology in addition to stormwater facility performance monitoring were presented in separate reports (King County 2011c, a, b). Collectively, these reports are the final post-development monitoring report for the Redmond Ridge and Trilogy UPDs. Presentation of results in Section 3 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 implemented since the 2007 UPD monitoring report (King County 2010).
- *Procedures*: briefly outlines the data collection and analysis procedures used.
- *Results*: summarizes key findings for the activity for the 2008 to 2010 water years.
- *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) in addition to modifications presented in the 2007 UPD monitoring report (King County 2010). 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. Additional analyses can be found in the midpoint and 2007 monitoring reports (King County 2006, 2010) – available online¹ or by request from King County.

The initiation and/or conclusion of the monitoring tasks described in this report relates to 75 percent buildout² of individual subbasins (Figure 2). Across both UPDs construction has surpassed the 75 percent buildout milestone in all subbasins except BBC³ (Table 1).

¹ <http://www.kingcounty.gov/environment/wlr/sections-programs/science-section/doing-science.aspx>

² 75 percent buildout means that (1) for residential areas 75 percent of the lots have completed roofs and driveways and (2) for commercial areas 75 percent 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) used professional judgment to estimate when conditions met the 75 percent buildout criteria for each subbasin.

³ Throughout this document, subbasins are denoted by their two- or three-letter abbreviation, as described in Table 1.

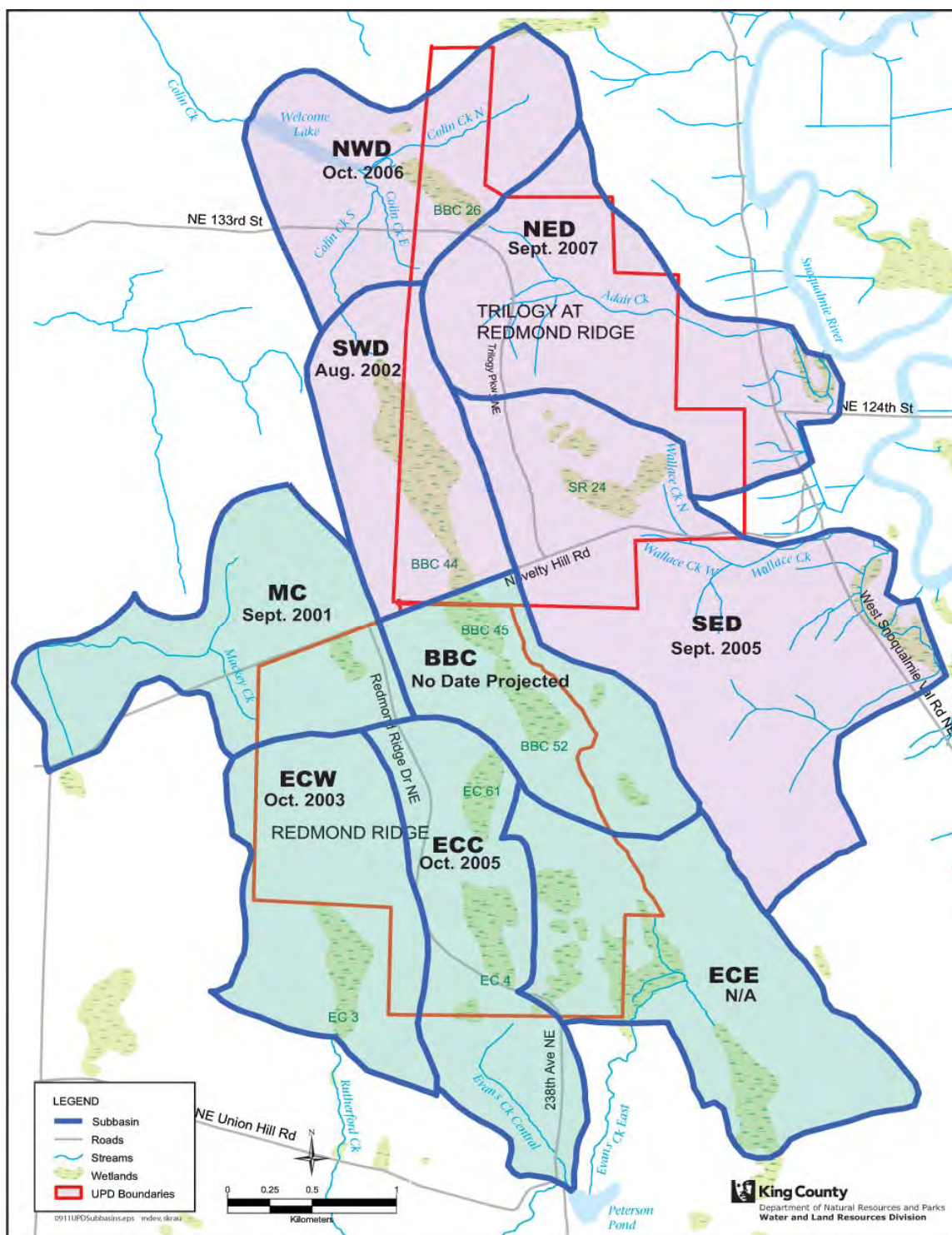


Figure 2. UPD subbasins.

Redmond Ridge (blue) is divided into five drainage subbasins (MC, ECW, BBC, ECC, and ECE), and Trilogy (purple) 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 when 75 percent buildout within that subbasin was reached (Lowe 2005, 2008, 2010).

Table 1. Development summary by UPD subbasin.

Status of development and subbasin buildout for the hydrologic basins draining Trilogy and Redmond Ridge at the end of the 2010 water year (adapted from Lowe 2005, 2008, 2010). Construction generally took 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	95%	Some areas of Parcels L, M, and N home construction remain
Southwest (SWD), Colin Creek South	2001	Aug-02	> 95%	Only one small retail pad remains
Southeast (SED), Wallace Creek ⁴	2001	Sep-05	> 95%	Condominium structures in Cascara at the Village 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 this part of the business park remain
Evans Creek East (ECE)	2003	N/A	100%	Very little development within Redmond Ridge boundaries

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.

1.1 Monitoring Program Goals

A major goal of the UPD monitoring program was to detect and evaluate significant changes to the natural resources that were a result of UPD development, including changes to streams, wetlands, fisheries, and groundwater. The program contained elements for assessing the status of and trends in aquatic macroinvertebrates, amphibians, fish, wetland vegetation, wetland and

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 as 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.

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).

The UPD monitoring program also evaluated whether stormwater facilities were working as designed in regard to flow control and water quality objectives. Elements contained in the program include verification of the hydrologic and water quality performance of runoff control facilities (King County 1999, 2001). These results in addition to wetland and stream hydrology results were presented in separate reports (King County 2011c, a, b).

1.2 Threshold Exceedance Criteria

The Trilogy and Redmond Ridge monitoring plans identified specific threshold exceedance criteria to ensure the effectiveness of protective actions (King County 1999, 2001). Exceedance of one or more thresholds triggered an investigation into the cause of the exceedance and required either: (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 YEARS 2008-2010

2.1 Trilogy

Trilogy construction activity in water years 2008-2010 included the L, M and N subdivisions (NED subbasin) plus Cascara Senior Living south of Novelty Hill Road (SED subbasin) (Figure 3). In addition to UPD construction, there were two road projects within the project area: (1) a left turn expansion on Trilogy Parkway NE just north of Novelty Hill Road; and (2) a Novelty Hill Road widening project between 242nd and 243rd. All four hydrologic basins within Trilogy reached the 75 percent buildout threshold by September 2007 (Table 1).

2.2 Redmond Ridge

Redmond Ridge construction activity in water years 2008-2010 was limited to three lots (BP 9-2, 16, 17) and a substation (lots BP-7 and U-2) within the business park (BBC subbasin) east of Redmond Ridge Drive NE (Figure 3). Clearing and construction of the Cedar Park Crescent Road, or C-2, extension project connecting Redmond Ridge with Redmond Ridge East began in 2010. Three of the four hydrologic basins reached 75 percent buildout by October 2005 (Table 1). As of October 2010, the BBC subbasin was only at 25 percent buildout with no projected 75 percent buildout date.

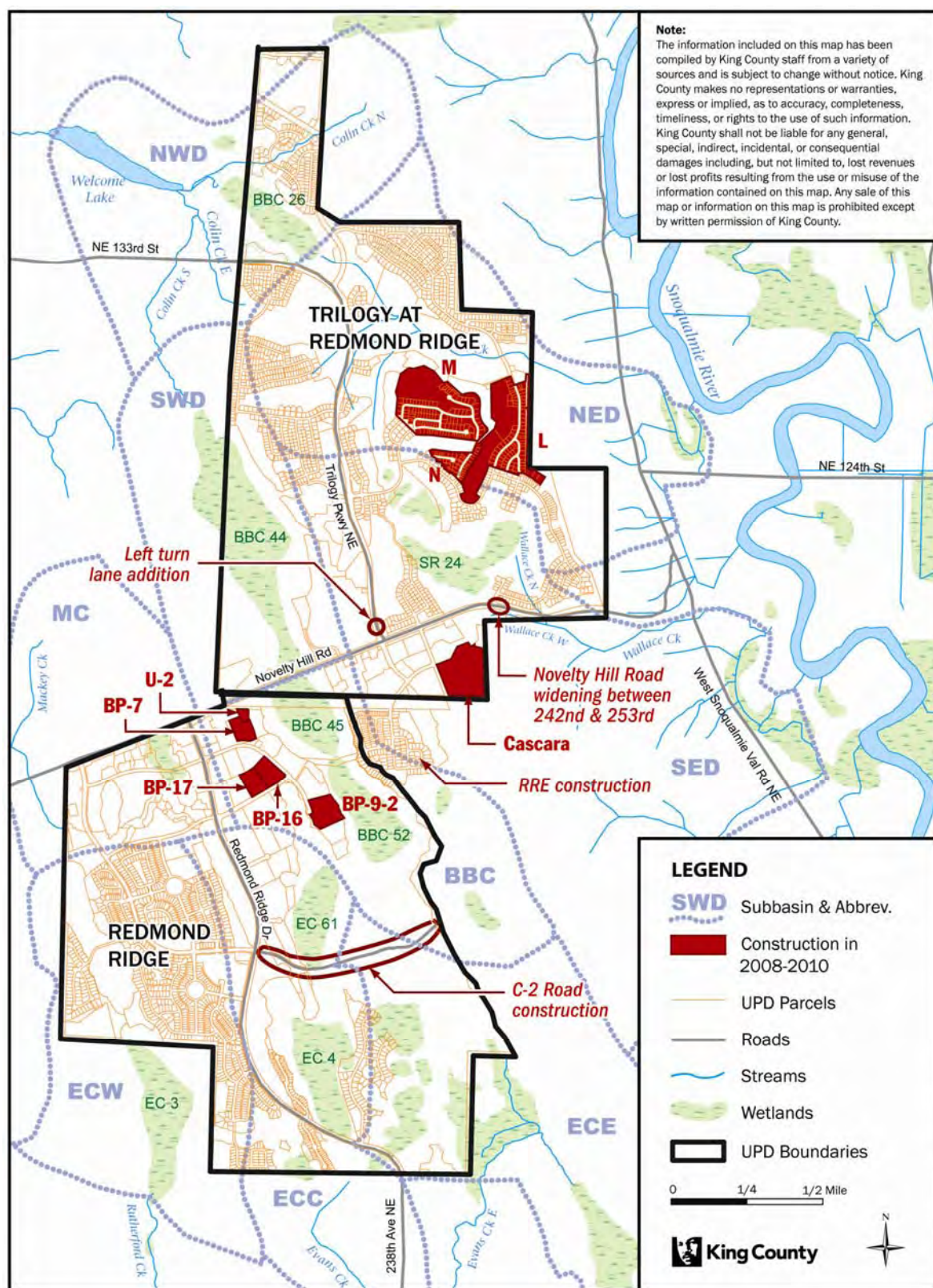


Figure 3. 2008-2010 Redmond Ridge and Trilogy UPD construction activities. Construction activities that occurred in 2008-2010 are indicated in red on the map (Lowe 2005, 2008, 2010).

2.3 Redmond Ridge East

Redmond Ridge East is generally out of the scope of this report; however, construction to the east of wetlands BBC-45 and BBC-52 are within the BBC subbasin, which also drains Redmond Ridge. Construction of the first subdivision began in summer 2007 in Redmond Ridge East and has been ongoing since.

3.0 NATURAL RESOURCES MONITORING ACTIVITY

Figure 4 shows all the locations and the types of monitoring required for the UPDs. Between 1998 and 2010 UPD-related monitoring has taken place on or within:

1. Ten creeks: 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. Twelve wetlands: BBC-26, BBC-44, BBC-45, BBC-52, BBC-UN1, EC-61, EC-4, EC-3, SR-24A, SR-24B, SR-24C, and SR-24D⁶.
3. One lake: Welcome Lake.
4. Twelve groundwater wells: Observation wells OBW-1R, -2R, -3R, -4R, -5, -6, -7R, -8, -10, -11, -12, and monitoring well MW-8 within Redmond Ridge and monitoring wells MW-1, -2, -4a, -4b, -4c, -4d, -5a, -5b, -5c, -5d, -6a, -6b, -6c, -6d, -7, and -8 within Trilogy.
5. Twelve stormwater facilities⁷: BC2-1, ECW2-1, ECW3-1, ECW3-3, MC1-1, MC2-1, MC4-1, and ECW1B1 within Redmond Ridge and NWD1-A, NWD4, NED9, and SWD3 within Trilogy.

Within the following monitoring sections, parameter-specific maps will highlight the monitoring that took place during the 2008-2010 water years. Monitoring efforts for 2008-2010 are also summarized in Table 2. Raw data were reported in the appendices of the 2007 UPD monitoring report but are generally not included in this report. Raw data are available by request from King County WLRD.

⁶ 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.

⁷ Stormwater facility monitoring was covered in separate reports for hydrology and water quality (King County 2011a, b).

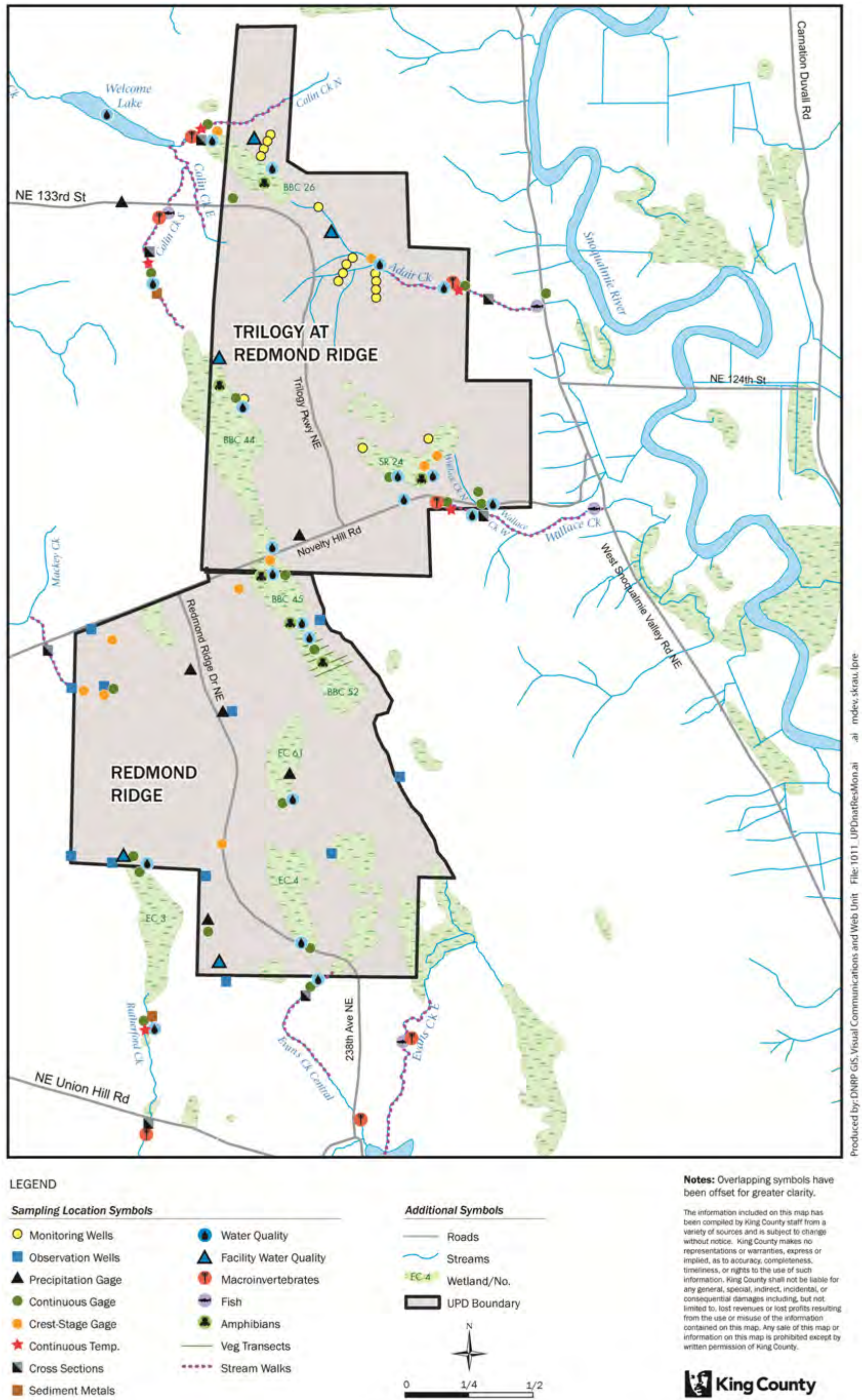


Figure 4. Sampling locations for natural resource monitoring parameters. Listed parameters were required as part of the Redmond Ridge and Trilogy post-development monitoring plans.

Table 2. 2008-2010 water year monitoring activities.

Natural resource monitoring activities summarized for the 2008 to 2010 water years at the Trilogy and Redmond Ridge UPDs by subbasin (listed from upstream to downstream).

	Macroinverts	Amphibians	Fish	Wetland Veg	Cross-sections	Water Quality	Groundwater
Redmond Ridge							
MC: Mackey Creek							
Mackey Creek					10		
Groundwater wells (OBW-1R, -2R, -10)							08-10
ECW: Evans Creek West (Rutherford)							
Rutherford Creek (18F)	08/10				10		
Groundwater wells (OBW-3R, -4R, -7R, -11)							08-10
ECC: Evans Creek Central							
EC-61						08/09	
EC-4						08/09	
Evans Creek Central (18B)	08				10		
Groundwater wells (OBW-6, -8)							08-10
ECE: Evans Creek East							
Evans Creek East	08/10		08/10				
BBC: Big Bear Creek							
BBC-52		08-10		08/10		08-10	
BBC-45 (2 WQ sites)		08-10				08-10	
Groundwater wells (OBW-5)							08-10
Trilogy							
SWD: Southwest Drainage (Colin South)							
BBC-44		08					
Colin Creek South (02D)	08/10		08/10		10		
Welcome Lake						08/09	
Groundwater wells (MW-8)							10
NWD: Northwest Drainage (Colin North)							
BBC-26 (2 WQ sites)		08/09				08/09	
Colin Creek North (02C)	08-10				10		
Groundwater wells (MW-6A to D)							10
NED: Northeast Drainage (Adair)							
ADCW1						08/09	
Adair Creek (53A or 53A u/s)	09/10		09/10		09/10	08/09	
Groundwater wells (MW-4A to D, -5A to D, -7)							10
SED: Southeast Drainage (Wallace)							
SR-24A						08/09	
SR-24B						08/09	
SR-24C		08/09				08	
Wallace Creek North (53C)						08/09	
Wallace Creek West (53B)	08/10				08/10	08	
Groundwater wells (MW-1, -2)							10

3.1 Precipitation

Because most hydrologic processes are closely linked to the timing, intensity, and duration of rainfall in a watershed, precipitation monitoring provided context for considering how 2008 through 2010 data should be interpreted. Precipitation was monitored continuously by the King County Water and Land Resources Division (WLRD) beginning in May 1995⁸ at Station 02V located 2,000 ft (610 m) west of the Trilogy UPD on NE 133rd Street (Figure 5). The locations of five other precipitation gages, three of which are no longer in place, are also shown on the map.

⁸ 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.

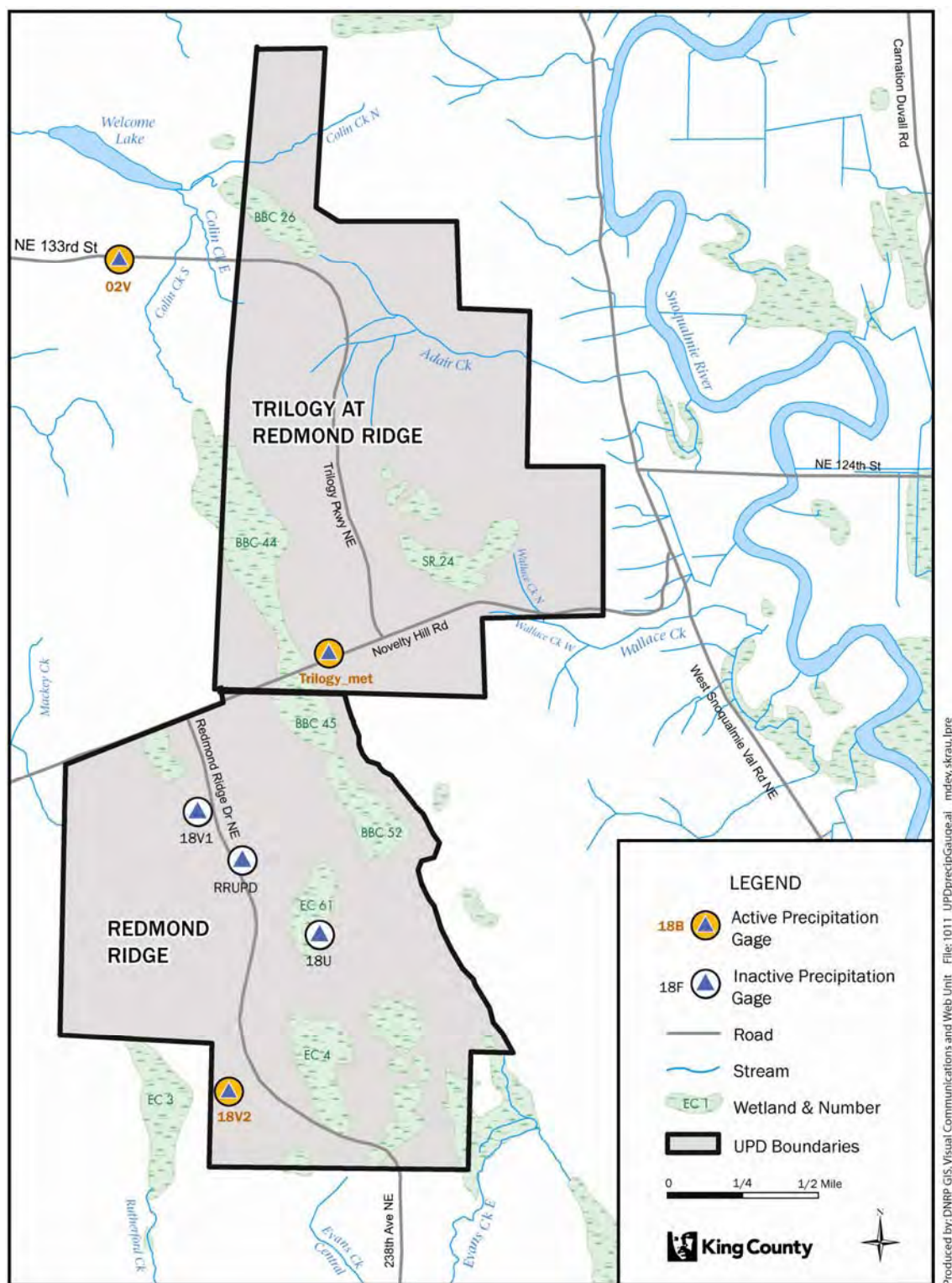


Figure 5. Location of five UPD-related precipitation gages. Inactive gages provided historical data, but the gages have been removed⁹.

⁹ Active dates for 5 UPD precipitation gages: 02V 10/1/94 to present; 18U 12/1/87 to 10/1/00; 18V1 1/1/99 to 2/1/05, re-established as 18V2 3/5/10 to present; 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

No change to monitoring plans. Station 02V will continue to be part of King County's ongoing monitoring programs despite the conclusion of all Redmond Ridge and Trilogy UPD monitoring¹⁰.

Procedures

The rain gages used a tipping bucket gage and 8-inch (20.3 cm) diameter funnel to measure rainfall. An electronic data logger recorded rainfall every 15 minutes in 0.01 inch (0.02 cm) increments and stored the gage output. Data were uploaded, the logger maintained, and the rain gage calibration checked approximately 10 times a year. Data accuracy was verified by comparing nearby gage records for anomalies. If equipment failure produced a gap in the record, rainfall was estimated from nearby recording gages and volunteer observations. Quality-controlled data were then exported to the King County Hydrologic Information Center web page. The two precipitation stations with the longest monitoring records were chosen to compile a 22 year precipitation record (water years 1989-2010¹¹). Monitoring data from Station 02V (1996-2010) and Station 18U (1989-2000) were obtained from the Hydrologic Information Center web page¹².

Results

Daily and cumulative monthly precipitation totals measured at Station 02V for water years 2008-2010 are presented in Appendix B (Tables B-1, -2, and -3). Water years 2008 and 2009 had total precipitations of 43.31 inches (110.0 cm) and 40.45 inches (102.7 cm), respectively, which are slightly below the 1989-2010 annual average of 44.99 inches (114.3 cm) (Figure 6). At 51.72 inches (131.4 cm), water year 2010 was the sixth wettest year between 1989 and 2010. July 2009 and May 2008 were the second and third driest months since 1996 with 0.10 inches (0.25 cm) and 0.11 inches (0.28 cm) of rain (Appendix B, Table B-4). In contrast, November of water year 2010¹³ was the fifth wettest month since 1996 with 9.75 inches of precipitation (24.8 cm). The maximum daily precipitation during water years 2008-2010 was 3.65 inches (9.3 cm) on December 3, 2007. Combined with the previous day's rainfall there was a two-day storm total of 5.09 inches (12.9 cm).

¹⁰ Therefore, precipitation station 02V will still be available to support ongoing Redmond Ridge East monitoring (Hugh G. Goldsmith and Associates Inc. 2007).

¹¹ Annual precipitation totals were averaged in water years 1996-2000 where data were available for both 02V and 18U).

¹² <http://green.kingcounty.gov/WLR/Waterres/hydrology/>

¹³ Water years begin on the October of the preceding year. Therefore November of water year 2010 is actually November 2009.

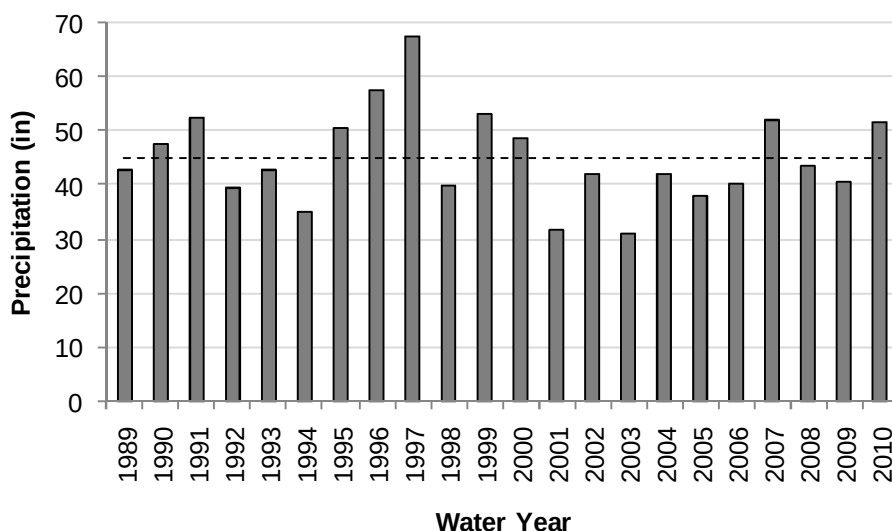


Figure 6. Cumulative annual precipitation for water years 1989 through 2010.

The horizontal line represents the mean annual precipitation from 1989-2010 (44.99 inches). Data from 1989-1995 are from Station 18U; from 1996-2000 are averaged from Station 18U and 02V; from 2001-2010 are from Station 02V.

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 ecosystems¹⁴ and provide a functional link between organic matter and fish in aquatic food webs. Analyses of the benthic macroinvertebrate community 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, which is unaltered by stocking or harvesting.

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 7) in 1999, 2000, 2001, and 2006. Beginning in 2007, sampling was spaced at 1-, 3-, and 5-year intervals relative to 75 percent buildout, and since then each site has been sampled approximately every other year. In 2010, macroinvertebrates were collected at all sites except Evans Creek Central, where landowner permission could not be obtained.

¹⁴ Lotic refers to moving waters such as streams or rivers.

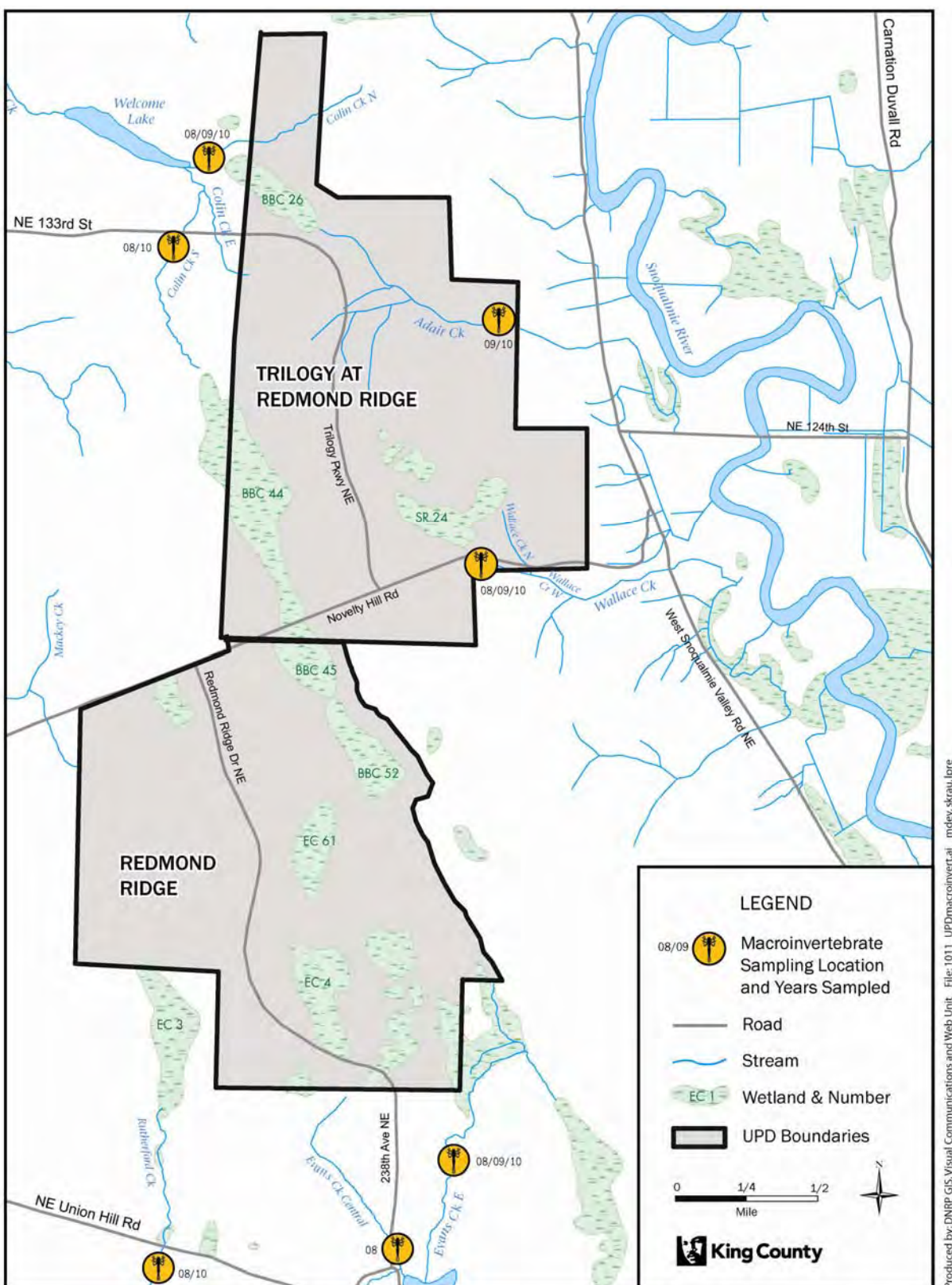


Figure 7. Location of seven UPD benthic macroinvertebrate monitoring stations.

Modifications

Beginning in 2007, all benthic macroinvertebrate sampling was shifted to a 1, 3, 5 year schedule following 75 percent subbasin buildout. In 2010, sampling was attempted at all sites including Adair Creek and Colin Creek North, which were 4 years following 75 percent subbasin buildout.

Sampling recommendations

Monitoring requirements outlined in the Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) have generally been met. No further sampling will be conducted.

Procedures

Macroinvertebrates were collected between late May and mid June of each year following the recommended sampling protocols outlined by Karr and Chu (1999) and summarized briefly here. At each location, a Surber sampler (500 μm mesh, 1 ft^2 [0.3 m^2] frame) was 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 was scrubbed by hand and examined before being placed outside of the Surber frame. A sturdy metal gardening hand tool was 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 was processed and condensed separately without compositing before being transferred to a sample container and preserved in the field with 95-100 percent ethanol (EtOH).

After field data collection each year, all samples were sent to a taxonomic laboratory for identification to the lowest possible taxonomic resolution¹⁵. Non-insect invertebrates (e.g., worms) were identified to family, order, or class. Each replicate was subsampled at 500 organisms¹⁶, but if fewer than 500 organisms were present, which was often the case, the entire sample was processed. Taxonomic data were uploaded to the Puget Sound Stream Benthos web page¹⁷.

Macroinvertebrates were 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 Wisseman (1998). These attributes were used to calculate the ten metrics that make up the Puget Lowland Benthic Index of Biotic Integrity (BIBI). The scores from the ten metrics were summed to provide an overall BIBI score ranging from 10 to 50 for each of the three replicates. The three replicate BIBI scores were then averaged for each site for a single overall BIBI score. The total BIBI score corresponds to biological condition ranging from very poor to excellent (see Appendix C for BIBI categories).

¹⁵ Exceptions to the lowest possible taxonomic resolution include identifying organisms to sub-family for Ceratopogoninae (biting midges) and to family level for Chironomidae (midges), Dolichopodidae (aquatic long legged flies), Dytiscidae (predaceous diving beetles), and Sciomyzidae (marsh flies). Capniidae (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 University of Washington students identified the organisms prior to 2001 and they identified all organisms in the sample and did not use a 500 organism subsample.

¹⁷ <http://www.pugetsoundstreambenthos.org/>

Results

Raw taxonomic macroinvertebrate data are available on the Puget Sound Stream Benthos web page¹⁸ for each sample date and location. Total BIBI scores are presented in Table 3; 2008-2010 scores range from a low of 14.0 (very poor) in 2010 to a high of 39.3 (good) in 2009 both at Adair Creek.

Table 3. BIBI Scores for UPD Creeks.

Grey shading indicates pre-UPD construction; green shading represents construction years; orange shading are years after 75 percent buildout for the subbasin. Values in red italics indicate greater than a 20 percent drop from the average preconstruction BIBI score (the threshold exceedance criteria).

Stream	1999	2000	2001	2006	2007	2008	2009	2010	20% Cutoff
Adair	30.0	35.3	42.7	32.7	33.3		39.3	<i>14.0</i>	28.8
Colin North	22.7	26.7	20.7	17.3		<i>17.3</i>	25.3	23.3	18.7
Colin South	22.7	27.3	26.7	24.7		22.7		22.0	18.1
Evans Central ¹⁹	26.0	28.0	29.0	<i>20.7</i>		28.7			20.8
Evans East	18.7	22.7	24.0	22.0		25.3		21.3	17.4
Rutherford	30.7	18.7	26.0	20.0		24.0		25.3	
Wallace	29.3	34.7	28.0	<i>25.3</i>	30.7	26.7		26.0	25.6

The average sample size for each replicate sample at each creek was frequently below 300 organisms, which is sometimes considered the minimum sample size for BIBI calculations (Table 4).

¹⁸ <http://www.pugetsoundstreambenthos.org/>

¹⁹ Evans Creek Central was not sampled in 2010 because landowner permission could not be obtained.

Table 4. Macroinvertebrate quantities for each replicate for UPD creeks.

Quantities less than 300 organisms are in bold italics.

Stream	Rep	1999	2000	2001	2006	2007	2008	2009	2010
Adair	1	247	691	162	31	83		379	66
	2	225	882	284	185	70		535	43
	3	259	451	351	73	210		407	27
Colin North	1	4436	1881	501	493		436	493	699
	2	1671	1166	566	204		552	377	226
	3	1994	1847	556	93		328	522	390
Colin South	1	360	732	324	299		133		134
	2	226	970	298	383		72		74
	3	409	639	544	250		201		73
Evans East	1	811	777	503	237		104		113
	2	1100	532	526	315		108		308
	3	2584	433	548	292		164		291
Evans Central	1	1849	161	329	73		213		
	2	1079	364	460	55		172		
	3	1250	224		103		400		
Rutherford	1	1708	417	551	512		161		184
	2	2531	278	435	254		58		135
	3	1507	114	531	235		87		160
Wallace	1	751	744	289	102	75	249		384
	2	821	549	346	208	105	294		461
	3	1139	502	490	563	202	441		257

Threshold Exceedance Criteria and Evaluation

Benthic macroinvertebrate threshold exceedance criteria were violated if there was a 20 percent or more decline in BIBI scores (King County 1999)²⁰. There were two instances in water years 2008 to 2010 and four instances overall where the threshold criteria were exceeded due to decreases in BIBI scores of more than 20 percent from the average preconstruction BIBI scores (Table 4). Each of the four instances will be discussed individually:

Adair Creek BIBI scores decreased substantially in 2010 to 14.0 compared to a preconstruction range between 30.0 and 42.7. A beaver dam blowout just upstream of Adair Creek Way on April 28, 2010, scoured the downstream channel. This dam breach, rather than upstream development impacts, was the likely cause of the large drop in BIBI scores at Adair Creek.

Colin Creek North BIBI scores decreased in 2006 and 2008 compared to preconstruction scores (20.7 to 26.7). However, the scores increased in 2009 and 2010 to levels within the preconstruction range.

Evans Creek Central had a decrease in BIBI scores to 20.7 in 2006 compared to the preconstruction score of 26.0 in 1999. Like Colin Creek North, BIBI scores rebounded to preconstruction levels in subsequent years (28.7 in 2008).

²⁰ The Redmond Ridge monitoring plan (King County 1999) used the BIBI threshold exceedance criteria, whereas the Trilogy monitoring plan (King County 2001) referred to a 20 percent 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.

Wallace Creek had a drop in BIBI scores in 2006 to 25.3 compared to preconstruction scores of 29.3 and 34.7 in 1999 and 2000. Scores increased in 2007 to 30.7, but decreased again in 2008 and 2010 to levels lower than preconstruction scores. A large debris slide took place in the upper reaches of Wallace Creek in 2005²¹. Ongoing deposition of fine materials from the slide area throughout the downstream sample area may have contributed to the drop in BIBI scores observed in 2006, 2008, and 2010 by filling in interstitial spaces between coarse gravel and cobble substrate, which are important macroinvertebrate habitat.

The very low numbers of organisms collected in various years throughout the sampling period calls into question the appropriateness of BIBI calculations at these locations (Table 4). Because the BIBI relies on several richness metrics (e.g., taxonomic, mayfly, stonefly, and caddisfly richness), BIBI scores could decrease when fewer organisms are observed. However, despite the reduced abundances, the post-development BIBI scores were still frequently within the range of scores observed during the predevelopment years.

Corrective Actions

Changed conditions could not be linked to UPD development, and as a result, 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 habitats²² (Richter and Azous 2001). Urbanization has been demonstrated to impact wetlands in numerous direct and indirect ways that result in habitat loss (Gibbs et al. 2005, Windmiller et al. 2008), 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 beginning in 2000 (BBC-52, BBC-45 d/s & u/s, SR-24C), 2001 (BBC-44), or 2002 (BBC-26). Phase out began after 2008 in some locations based on subbasin buildout (Figure 8).

²¹ This debris slide was investigated by WLRD staff who determined it was not caused by Redmond Ridge or Trilogy UPD development.

²² Lentic refers to still waters such as lakes and ponds.

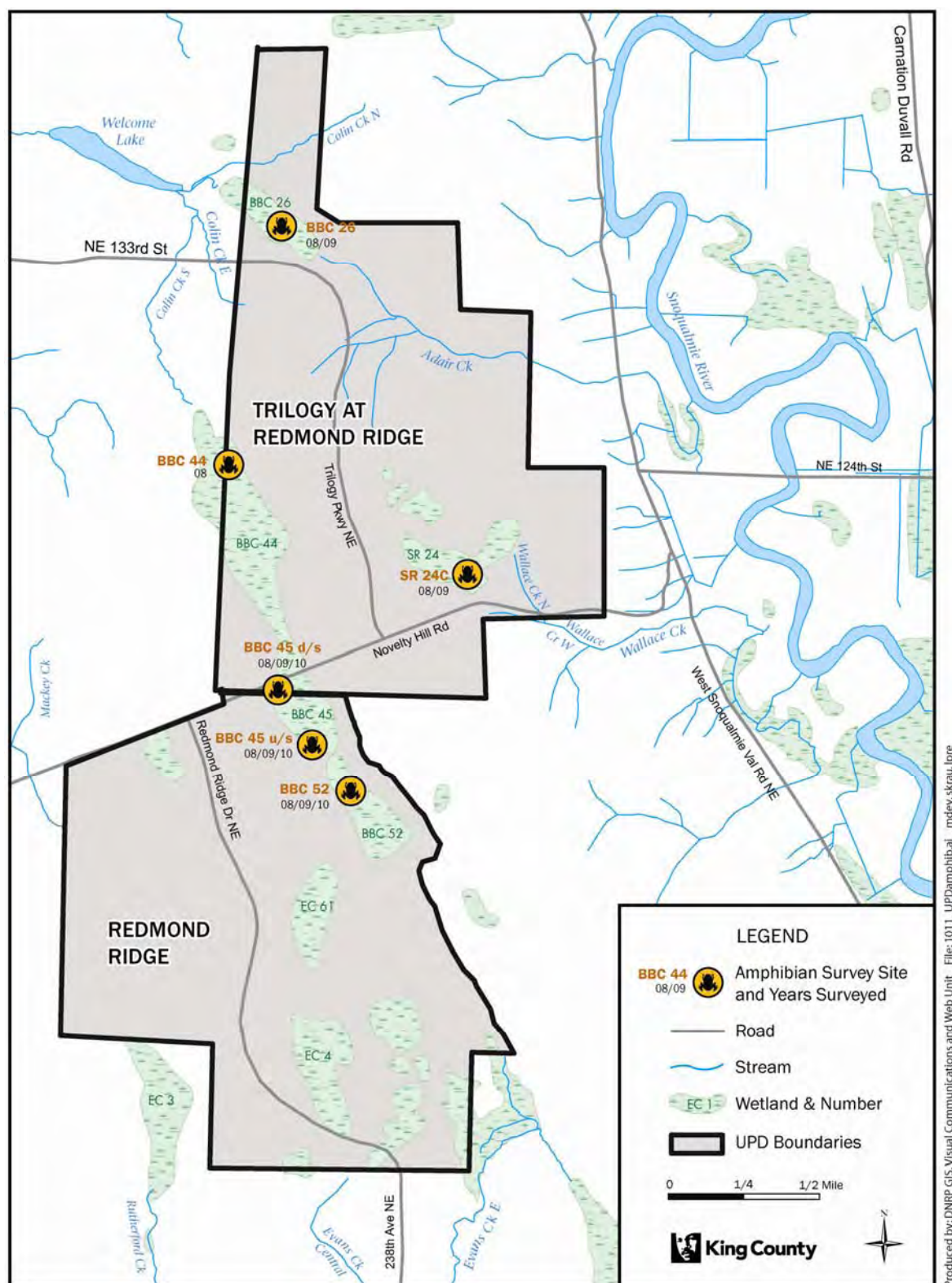


Figure 8. Location of amphibian breeding surveys.

Amphibian breeding surveys were conducted at all six sampling locations on five wetlands in 2008; at five locations on four wetlands in 2009; and at three locations on two wetlands in 2010.

Modifications

No modifications to the amphibian breeding monitoring activities have occurred since 2007.

Sampling recommendations

Monitoring requirements outlined in the Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) have been met at BBC-44, SR-24c, and BBC-26, and therefore these wetlands will no longer be sampled. It is recommended that amphibian breeding sampling also be concluded at BBC-45 and BBC-52. Within Redmond Ridge, no parcels remain to be developed that will drain to BBC-52. Concurrent development of Redmond Ridge East will complicate detection of Redmond Ridge impacts. In addition, monitoring at other wetlands has been concluded and no impacts have been definitively linked to UPD development.

Procedures

Amphibian breeding surveys generally followed methods outlined by Thoms et al. (1997) and modified by Richter and Ostergaard (1999). Two annual egg mass surveys were conducted by two biologists in the first three weeks of March and the second two weeks of April. Throughout the UPD monitoring efforts, the schedule of these surveys varied slightly from year to year based on the timing of oviposition. Rain, high winds, and overcast conditions were avoided whenever possible to maximize visibility through the water column. Surveys were 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 were 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, paedomorphs²³, juveniles, and adults were also identified to species if possible, and calling frogs were noted and identified by call when heard.

Results

There were three threshold exceedance criteria associated with amphibian breeding monitoring related to species richness, egg mass abundance, and egg mass mortality and the results that follow are presented under these three subheadings.

Amphibian richness

Egg masses of four native amphibian species were commonly found during the monitoring periods at the five surveyed wetlands. These four species included northwestern salamanders (*Ambystoma gracile*), northern red-legged frogs (*Rana aurora*), Pacific treefrogs (*Pseudacris regilla*), and to a lesser extent long-toed salamanders (*Ambystoma macrodactylum*) (Figure 9). 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.

²³ 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 9). There were no obvious trends regardless of construction and development in the basins.

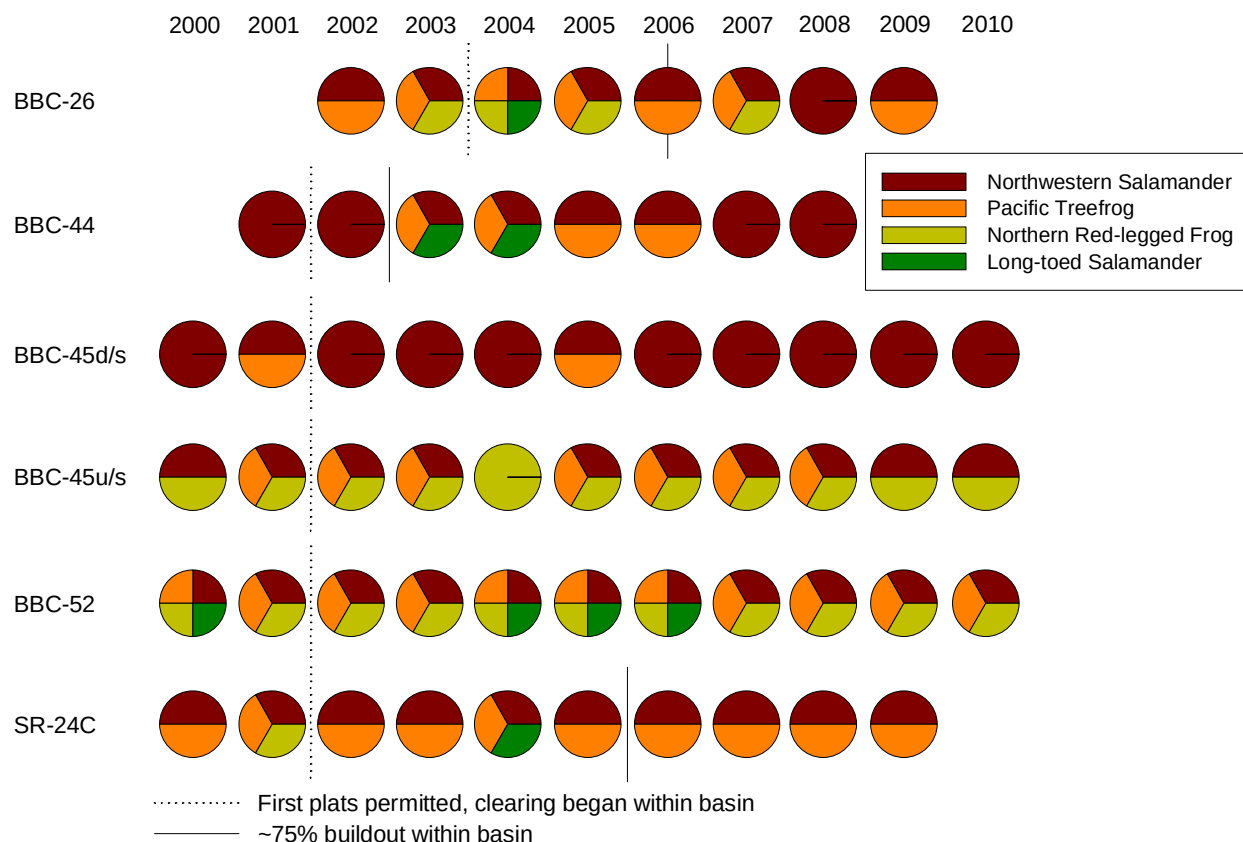


Figure 9. Species composition of amphibian egg masses at various UPD wetland sites.

The proportion of the pie assigned to each species was based on species richness and was not representative of abundance. Permit and clearing start dates were estimated from development phasing maps (KPFF Consulting Engineers 2004, Otak Incorporated 2006) combined with aerial photo interpretation (1998, 2000, 2002, 2005, 2007, 2009). 75 percent buildout dates were estimated by DDES (Lowe 2005, 2008, 2010).²⁴

Egg mass abundance

Egg mass abundances for wetland-breeding amphibians are shown for all six wetland locations from 2000 to 2010 in Table 5. Long-toed salamander egg mass abundances were 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 2007-2010. Pacific treefrog and northern red-legged frog egg masses were most commonly observed in BBC-52. Northern red-legged frog egg masses nearly quadrupled in 2008 to 186 at BBC-52, before dropping to 59 and 43 egg masses in 2009 and 2010. Pacific treefrog egg mass abundances have declined across all wetland locations, though most notably at BBC-52 and SR-24C. A low of 12 and 39 Pacific treefrog egg masses were observed in BBC-52 in 2009 and 2010, respectively, and a low of one Pacific treefrog egg mass was observed in SR-

²⁴ 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.

24C in 2008 and 2009. Northwestern salamander egg masses were the most widely occurring 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 plus in BBC-52 since 2007. Northwestern salamander egg mass abundance appears to have increased at BBC-45d/s and BBC-52 relative to preconstruction baseline data.

Table 5. Amphibian egg mass abundance from 2000 to 2010.

Two surveys were conducted each year and the table numbers represent the maximum number of egg masses observed between the two surveys. Shading represents development status in each subbasin: gray is predevelopment, green is during construction, and orange is post 75 percent buildout. Blank cells indicate that no survey was done.

Survey was done:

	Long-toed Salamander												Pacific Treefrog										
	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10		'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10
BBC-26			0	0	4	0	0	0	0	0					9	10	22	43	19	6	0	7	
BBC-44		0	0	2	2	0	0	0	0				0		0	2	1	8	3	0	0		
BBC-45d/s	0	0	0	0	0	0	0	0	0	0	0		0	4	0	0	0	1	0	0	0	0	0
BBC-45u/s	0	0	0	0	0	0	0	0	0	0	0		0	16	14	11	0	4	1	5	1	0	0
BBC-52	3	0	0	0	15	1	5	0	0	0	0		51	190	89	559	74	50	152	456	91	12	39
SR-24C	0	0	0	0	5	0	0	0	0	0			41	82	15	20	11	12	4	6	1	1	

	Northern Red-legged Frog												Northwestern Salamander										
	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10		'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10
BBC-26			0	2	3	4	0	6	0	0					329	233	214	268	358	610	293	319	
BBC-44		0	0	0	0	0	0	0	0				149	202	169	175	57	211	215	110			
BBC-45d/s	0	0	0	0	0	0	0	0	0	0	0		19	42	80	46	39	42	87	76	82	68	88
BBC-45u/s	10	3	2	2	1	2	1	3	4	3	4		7	2	20	3	0	5	10	13	10	13	1
BBC-52	21	13	25	40	89	42	42	48	186	59	43		86	36	103	33	70	19	66	108	135	268	175
SR-24C	0	1	0	0	0	0	0	0	0				91	207	265	282	257	293	146	190	184	285	

Egg mass mortality

Mean egg mass mortalities²⁵ were 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, and 96-100). No long-toed salamander egg masses were observed in 2008-2010, and consequently they were omitted from the mortality evaluation. Mean egg mass mortality did not increase by 20 percent or more (the threshold exceedance level) compared to preconstruction ranges during any sample periods at BBC-26, BBC-44 and SR-24c (Table 6). Pacific treefrog egg mass mortality exceeded the established threshold in 2009 (50.5 percent) and 2010 (32.7 percent). Northwestern salamander egg mass mortality exceeded the threshold in 2009 (49.1 percent) at BBC-45u/s and in each of the last four years at BBC-45d/s: 2007 (67.3 percent), 2008 (85.6 percent), 2009 (95.0 percent), and 2010 (61.7 percent).

²⁵ Mortality estimates were categorical and subjective. It was 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 was up to best professional judgment, which may vary by observer.

Table 6. Amphibian egg mass mortality.

Exceedances of the egg mass mortality threshold are listed here.

Wetland	Species	Preconstruction Range (%)	Threshold (20% Increase)	Exceedances
BBC-26	NW salamander	1 - 4.8	24.8	
	Pacific treefrog	0 - 0.7	20.7	
	N. red-legged frog	N/A	20.0	
BBC-44	NW salamander	0.3 - 8.9	28.9	
	Pacific treefrog	N/A	20.0	
BBC-45d/s	NW salamander	0 - 35.7	55.7	'07 (67.3), '08 (85.6), '09 (95.0), '10 (61.7)
	Pacific treefrog	5.4 - 5.4	25.4	
BBC-45u/s	NW salamander	0.4 - 9.3	29.3	'09 (49.1)
	Pacific treefrog	5.4 - 5.4	25.4	
	N. red-legged frog	0 - 7.2	27.2	
BBC-52	NW salamander	0.2 - 9.8	29.8	
	Pacific treefrog	3.7 - 3.9	23.9	'09 (50.5), '10 (32.7)
	N. red-legged frog	0.2 - 16.2	36.2	
SR-24c	NW salamander	3 - 7.9	27.9	
	Pacific treefrog	0.7 - 2	22.0	

Threshold Exceedance Criteria and Evaluation

There were three threshold exceedance criteria associated with amphibian breeding monitoring related to species richness, egg mass abundance, and egg mass mortality. Criteria for violating these thresholds are defined below and the sub-bullets summarize the results related to each threshold.

Species richness: Threshold exceedance criteria were violated if any one species that formerly bred in the wetland disappears for two consecutive years.

- Species richness of breeding amphibians fluctuated across the monitoring period with no clear links to the timeline of UPD development (Figure 9).
- The species richness observed at each sampling location in the final year of monitoring (2008, 2009, or 2010) was the same as at least one year of predevelopment species richness across all wetland locations.

Abundance: Threshold exceedance criteria were violated if significant reduction in abundance of egg masses of northwestern salamanders or northern red-legged frogs²⁶ was observed for two consecutive years.

- Amphibian egg mass abundance fluctuated considerably from year-to-year, even in the absence of development impacts (e.g., 91 and 207 northwestern salamander egg masses preconstruction in 2000 and 2001, respectively, at SR-24c).

²⁶ 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.

- In general, egg mass abundances of northwestern salamanders and northern red-legged frogs between 2008 and 2010 were within the range of preconstruction abundances (Table 5).
- In the case of northwestern salamanders at BBC-45d/s and BBC-52 and northern red-legged frogs at BBC-52, the 2008-2010 egg mass abundances greatly exceeded preconstruction abundances (Table 5).
- Although not specifically called out in the exceedance threshold, Pacific treefrog egg mass abundances have declined across all wetland locations, though most notably at BBC-52 and SR-24C. A low of 12 and 39 Pacific treefrog egg masses were observed in BBC-52 in 2009 and 2010, respectively, and a low of one Pacific treefrog egg mass was observed in SR-24C in 2008 and 2009 (Table 5).

Mortality: Threshold exceedance criteria were violated if egg mass mortality increased by 20 percent or more for northwestern salamanders or northern red-legged frogs.

- Egg mass mortality increased by more than 20 percent compared to preconstruction data for northwestern salamanders at wetlands BBC-45d/s²⁷ and BBC-45u/s in some years (BBC-45d/s: 2007, 2008, 2009, and 2010; BBC-45u/s: 2009) (Table 6). BBC-45d/s repeatedly had mortality levels above 25 percent and up to 53 percent in 2001, 2002, and 2005 although very little UPD clearing or development had occurred within the BBC subbasin. Therefore, the egg mass mortality at BBC-45d/s may be unrelated to UPD development.
- Beginning in 2006, clearing and construction within the BBC subbasin increased, including substantial development to the east in Redmond Ridge East. From this time forward it will be increasingly difficult to distinguish whether potential impacts are coming from Redmond Ridge or Redmond Ridge East.
- Northern red-legged frog egg mass mortality never increased by more than 20 percent at any of the wetland locations.

Corrective Actions

The exceedances noted above related to northwestern salamander egg mass mortality at BBC-45d/s and BBC-45u/s cannot be directly linked to UPD development, and no corrective actions are recommended.

3.4 Fish

Fish are commonly used bioindicators reflecting cumulative impacts to aquatic environments. Fish react to changing chemical and physical properties, including impacts 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

²⁷ See 2007 UPD report (King County 2010) for a discussion of impacts to BBC-45d/s. 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. These impacts were already present before UPD construction began.

that urban development that minimizes connected impervious surfaces²⁸ 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 modeled this buffer preservation approach. Fish sampling on up to four streams draining the UPDs (Adair, Colin South, Evans East, and Wallace Creeks) tested whether UPD development impacted fish populations (Figure 10).

²⁸ 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.

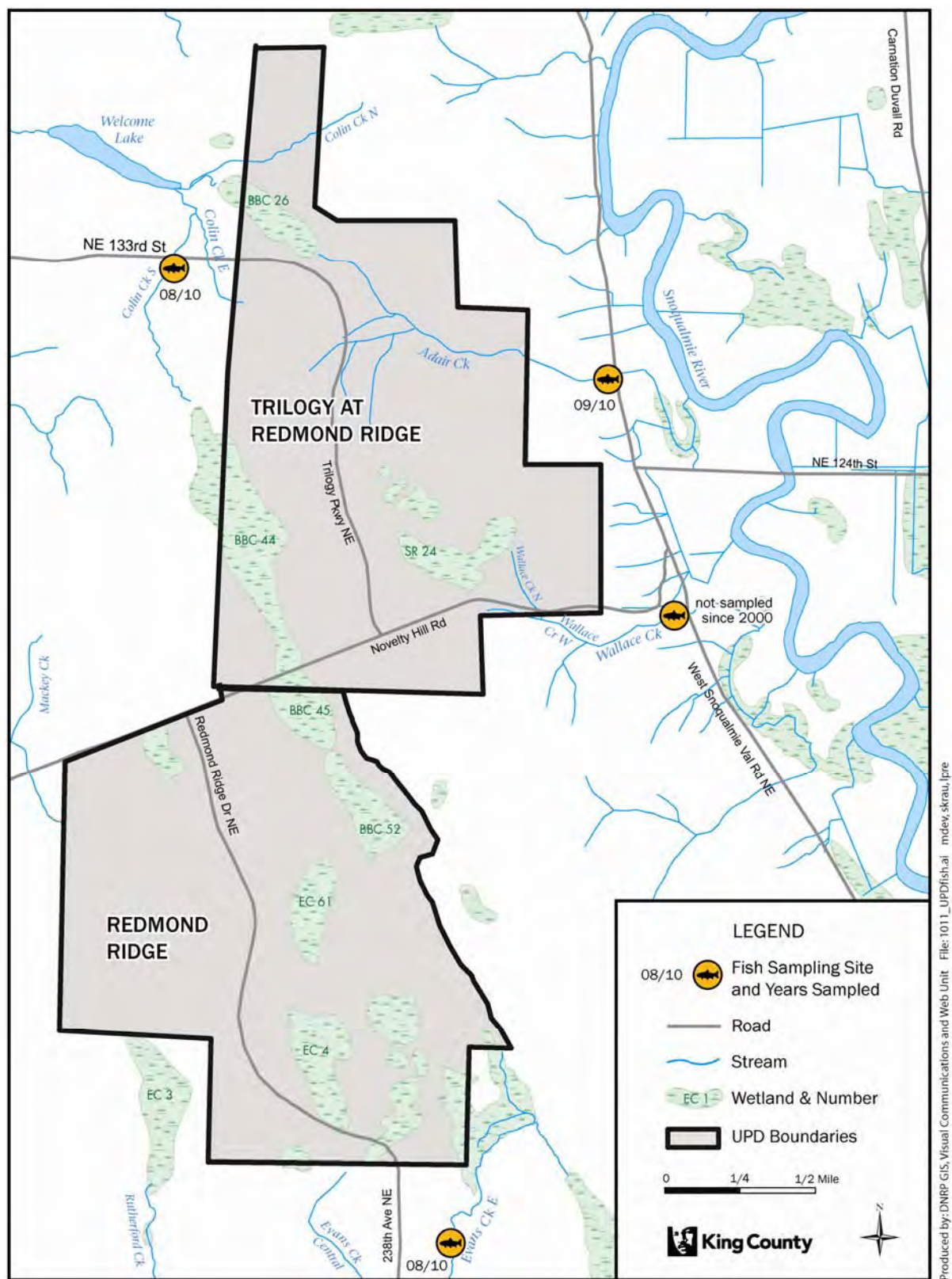


Figure 10. Fish sampling locations.
Fish sampling was conducted at up to three creeks per year in 2008, 2009, and 2010.

Modifications

Beginning in 2007, all fish sampling was shifted to a 1, 3, 5 year schedule following 75 percent subbasin buildout. In 2010, sampling was attempted at all sites including Adair Creek, which was 4 years following 75 percent subbasin buildout. Wallace Creek was removed from the monitoring schedule because of an inability to gain property-owner permission to conduct fish sampling, and relocating the sample reach would not allow a comparison of pre- and post-development conditions.

Sampling recommendations

Monitoring requirements outlined in the Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) have generally been met. No further sampling will be conducted.

Procedures

Crews used four-pass electrofishing removal/depletion methods in 1991 and 2000 and three-pass methods in 2006 through 2010 to survey fish within reaches either approximately 60 or 100 m (196 or 328 ft) in length²⁹ (Zippin 1956, 1958, Platts et al. 1983). Since 2000, surveys have been conducted in June; however, 1991 sampling took place in August, September, or December³⁰. At each site, crews used a Smith-Root type VII electrofisher with dip nets to collect fish, which 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 measured³¹ prior to being released downstream of the sample reach. In 1991 and 2009, fish were sedated with MS-222 (tricaine methanesulfonate) to facilitate handling. Sedatives were not used in the other 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 through 2010. No net was placed at the upstream end of the reach in 2006, however 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.

To make comparisons across years, the three-pass cumulative abundance for each species was calculated. Population estimates are inherently variable and were not calculated for the purposes of this report.

Results

In 2008, 162 fish were collected in Colin Creek South including 5 coho (*Oncorhynchus kisutch*), 128 cutthroat trout (*Oncorhynchus clarki*), and 29 rainbow trout (*Oncorhynchus mykiss*), and 175 fish were collected in Evans Creek East including 174 cutthroat trout and 1 green sunfish (*Lepomis cyanellus*) (Table 7). In 2009, 78 fish were collected in Adair Creek including 49 coho and 29 cutthroat trout. In 2010, 13 fish were collected in Adair Creek including 12 coho and 1 cutthroat trout; 260 fish, all cutthroat trout were collected in Colin Creek South; and 149 fish

²⁹ Sample reaches were ~ 60 m in length in 1991 and 92-100 m in length in 2000, 2006 and 2007.

³⁰ Evans Creek East was sampled in December 1991 because the channel was dry in September 1991.

³¹ 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, 2009, and 2010 and total length was recorded in 2006, 2007, and 2008. Because of time limitations, only a subset of fish were measured in 2010.

including 144 cutthroat trout and 5 pumpkinseed sunfish (*Lepomis gibbosus*) were caught in Evans Creek East. In addition to the fish, crews also frequently captured Pacific giant salamanders (*Dicamptodon tenebrosus*) and crayfish (*Pacifasticus leniusculus*)³².

Table 7. Summary by species and pass for 2000 and 2006-2010 fish sampling.

Year	Species	Adair				Colin South				Evans East				Wallace			
		1	2	3	Total	1	2	3	Total	1	2	3	Total	1	2	3	Total
2000 ³³	Coho	13	11	6	30												
	Cutthroat	45	38	36	119	18	24	19	61	78	44	43	165	37	30	23	90
2006	Coho	29	16	14	59	3	6	6	15								
	Cutthroat	3	1	6	10	37	9	6	52	52	25	11	88				
	Pumpkinseed											1	1				
2007	Coho	44	18	12	74												
	Cutthroat	16	9	8	33												
	Rainbow	38	10	7	55												
2008	Coho	7	4	1	12												
	Cutthroat					4	1		5								
	Green Sunfish					50	49	29	128	117	38	19	174				
2009	Coho																
	Cutthroat																
	Rainbow					19	10		29	1			1				
2010	Coho	25	15	9	49												
	Cutthroat	18	7	4	29												
	Pumpkinseed	10	2		12												
2010	Coho	1			1	140	81	39	260	80	43	21	144				
	Cutthroat									3	2		5				
	Pumpkinseed																

Species Richness

Fish species richness varied throughout the sampling period; however, cutthroat trout were captured during every sampling event in every location (Table 8). In Adair Creek, coho were captured every year sampled except 1991. Rainbow trout (*Oncorhynchus mykiss*) were identified once each in Adair Creek (2007) and Colin Creek South (2008). Sculpin (*Cottus* sp.) were identified in Adair Creek in 2006 and 2007. And one species of non-native sunfish (either green or pumpkinseed) was found in Evans East in 2006, 2008, and 2010.

³² The electrofishing surveys were not designed to estimate amphibian or crayfish populations; therefore, only presence or absence was noted.

³³ 4 passes were conducted in 2000. The 4th pass caught 7 coho and 30 cutthroat trout in Adair Creek and cutthroat trout only as follows: 8 in Colin Creek South, 37 in Evans Creek East, and 14 in Wallace Creek.

Table 8. Species collected during electrofishing sampling dates on UPD creeks.

1991 data were collected in August. All other sampling was conducted in June. Shading indicates development status in each subbasin: black is predevelopment, green is during construction, orange is post 75% buildout. DNS means 'did not sample'.

Year	Adair	Colin South	Evans East
1991	cutthroat	cutthroat	cutthroat
2000	cutthroat, coho	cutthroat	cutthroat
2006	cutthroat, coho, sculpin	cutthroat, coho	cutthroat, pumpkinseed
2007	cutthroat, coho, sculpin, rainbow	DNS	DNS
2008	DNS	cutthroat, coho, rainbow	cutthroat, green sunfish
2009	cutthroat, coho	DNS	DNS
2010	cutthroat, coho	cutthroat	cutthroat, pumpkinseed

Baseline surveys in 1991 indicated that cutthroat trout were the dominant fish species in the UPD creeks, and cutthroat were observed at each sampling date and location regardless of development levels. 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 warmwater species (Lyons et al. 1996). With the exception of the two sunfish species observed in Evans Creek East (where very little UPD development occurred and therefore all data are considered 'predevelopment'), the collected species have all been native and are 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 program³⁴ could explain the periodic presence of coho in Adair and Colin South Creeks after they were not found in the initial 1991 survey.

Sculpins were observed only in 2006 and 2007 at Adair Creek; however, they are frequently missed when electrofishing because they are benthic species. Benthic fish swim in short bursts and sink when stunned. Because they sink, they are more difficult to capture with electrofishing methods, and this difficulty is exacerbated 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). 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 during sampling efforts in 2007 at Adair Creek and again at Colin Creek South in 2008. Features and colors vary greatly among salmonid 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). Only 2 of the 55 rainbow trout observed in 2007 at Adair Creek were greater than 80 mm (3.1 in) in length³⁵, and only 1 of

³⁴ 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.

³⁵ The two larger rainbow trout observed at Adair Creek in 2007 were 103 and 110 mm (4.1 and 4.3 in) in length.

the 58 rainbow trout in 2008 at Colin Creek South approached 80 mm (3.1 in)³⁶. The presence of the 3 larger fish allowed the WLRD fish sampling crew to positively confirm the rainbow trout identification. In all cases, smaller salmonids were identified to species using best professional judgment; however, it is possible that identification errors occurred.

Threshold Exceedance Criteria and Evaluation

Fish threshold exceedance criteria were violated and could trigger corrective actions if any fish species present before UPD development should disappear in any sampling season (King County 2010). Similar to predevelopment results, coho and cutthroat trout were the dominant fish species at Adair Creek, and cutthroat trout were the dominant species at Colin Creek South and Evans Creek East.

Corrective Actions

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

3.5 Wetland Vegetation

Wetland BBC-52 is a large, 11.1-hectare (27.4-acre) class 1 wetland that is part of a connected string of wetlands that forms a codified wildlife corridor. Water levels generally reflect seasonal precipitation patterns (King County 2011c); however, past beaver activity controls the level during high flows because of old dams still in place (Raedeke Associates Inc. 1995). BBC-52 is composed of a combination of wetland habitat types including open water, scrub-shrub, and forested (Raedeke Associates Inc. 1995) and it was characterized as a bog in the 1981 King County Wetland Inventory (King County 2002). Bogs are unique, highly sensitive ecosystems (Kulzer et al. 2001). Therefore, special safeguards were instituted to protect BBC-52 in addition to the 60-m (200-ft) wetland buffer averaging. For example, all Redmond Ridge stormwater is diverted away from BBC-52 and only rainwater draining roofs is directed into the system.

Changes in hydrology or water quality associated with development could influence wetland vegetation (Azous and Horner 2001, Horner 2001). Therefore, vegetation monitoring was implemented at BBC-52 in even years starting in 2000 to detect any changes in the wetland plant communities.

Modifications

No modifications to the wetland vegetation monitoring activities have occurred.

Sampling recommendations

It is recommended that vegetation sampling at BBC-52 be concluded. The BBC basin within Redmond Ridge has not reached 75% buildout, which dictates the monitoring duration, and no date is projected at this time. Despite this lag in development, no parcels remaining to be developed within the Redmond Ridge UPD will drain to BBC-52. In addition, ongoing development and buildout of Redmond Ridge East along the eastern margins of BBC-52 will make it challenging to attribute impacts only to Redmond Ridge.

³⁶ The one large rainbow trout observed at Colin Creek South in 2008 was 79 mm (3.1 inches) in length.

Procedures

Vegetation surveys were performed on wetland BBC-52 between June 28 and July 26 in even years (2000, 2002, 2004, 2006, 2008, and 2010) following methods described by Elzinga (1998). Six permanent transects were established 50 m (16 ft) apart and perpendicular to a 300 m (984 ft) baseline transect set at 140 degrees (not corrected for declination). These six transects crossed the open water portions of the wetland and ranged from 105 to 240 m (344 to 787 ft) in length. The ends of each transect were marked with rebar and flagging (which was replaced during sampling as needed). PVC pipes, each marking the center of a circular quadrat³⁷, were spaced 30 m (98 ft) apart with between five and nine quadrats per transect (Figure 11).

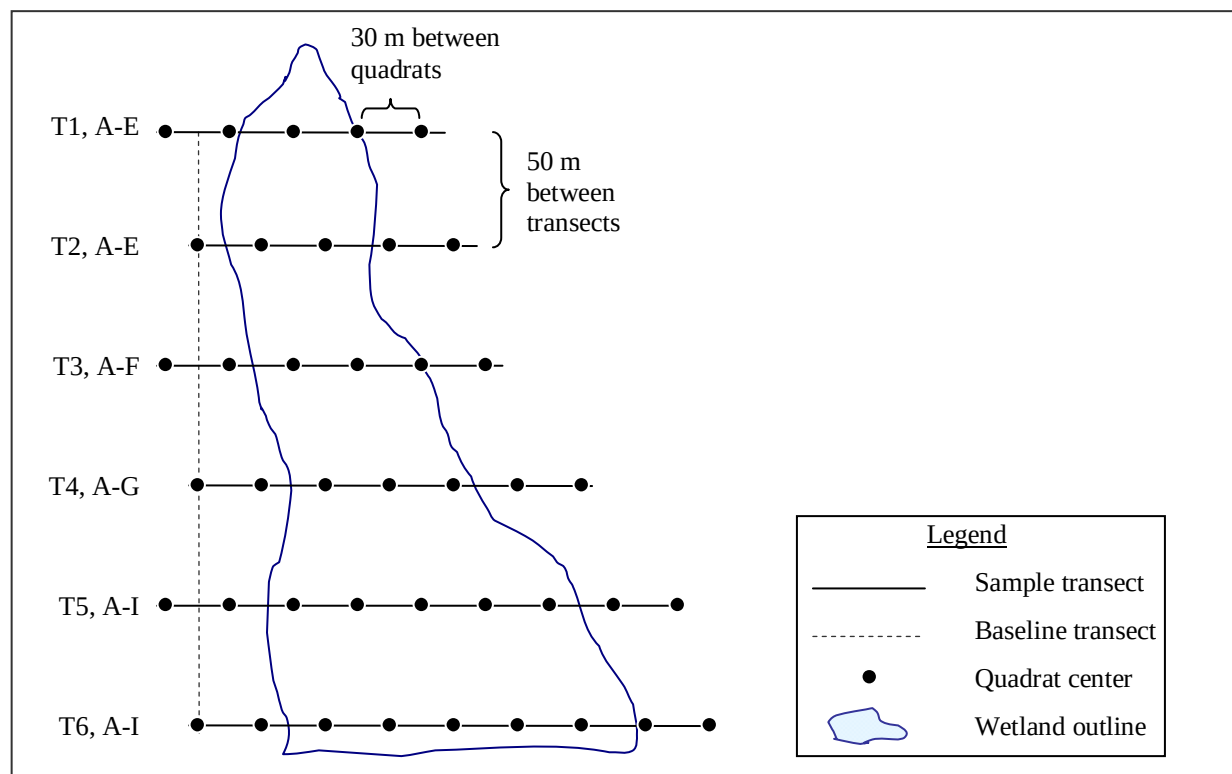


Figure 11. BBC-52 vegetation sampling transect and quadrat set up. The baseline transect was established at 140 degrees with the sample transects set perpendicular at 50 degrees.

The size of each quadrat sampled was determined by the type of vegetation community, which was classified in 2000, the first year of sampling, as forest, shrub, or herbaceous for each plot (Table 9)³⁸. All plants within each quadrat were identified to species when possible³⁹. Additional plant-like organisms were identified into general categories such as mosses and lichens. Percent aerial cover was estimated into one of six percent cover classes (0 to <0.5, 0.5

³⁷ A quadrat is a plot of land of known area, which is typically square, rectangular, or circular in shape and is used for ecological studies.

³⁸ There were 41 total quadrats typically classified into the following strata: 19 forest, 15 shrub, and 7 herbaceous. However, despite efforts to keep the strata classification and therefore the quadrat size uniform from year to year, there were deviations: one quadrat in 2000, two quadrats in 2002, and four quadrats in 2006 were classified differently than all other years. See Appendix D for strata classifications.

³⁹ Plant identification occasionally required examination back at the lab.

to 5, 6 to 25, 26 to 50, 51 to 95, and 96 to 100) for each species within a quadrat. For the purposes of this survey, aerial cover was defined as the amount of ground space within the quadrat overlain by canopies of individual plants or summations of canopies from multiple plants of the same species. Openings created by separated leaves within the canopy were not subtracted out, and an individual plant with more than 60 percent of its mass within the boundaries of the quadrat was included in this cover estimate (less than 60 percent is not included). Cover classes were also estimated for open water, wood, duff, and bare ground when present.

Table 9. Wetland vegetation strata and quadrat size.

Strata	Quadrat radius (m)	Definition
Forest	10	> 30% aerial cover of trees > 6 m (20 ft) tall
Shrub	5	< 30% aerial cover of trees > 6 m tall <i>and</i> > 30% aerial cover of shrubs and trees < 6 m tall
Herbaceous	1	dominated by plants without woody stems and < 30% aerial cover of shrubs or trees

Taxonomic effort and resolution was not consistent between years. In addition, identification of grasses, sedges, and rushes to species can be very difficult and time consuming and requires a high level of expertise. Therefore, to enable detection of actual changes in plant composition rather than changes in field personnel or level of effort and expertise, data were lumped for certain taxa before any data analyses were conducted (see Appendix E for list of lumped taxa).

Only vascular plants were considered for analysis. Therefore non-vascular organisms including mosses, liverworts, algae, and lichens were omitted in addition to aerial cover or presence/absence of open water, wood, duff, and bare ground.

Results

Between 2000 and 2010, 129 species of vascular plants were observed and identified during BBC-52 wetland vegetation surveys within the 41 quadrats (see Appendix F for a complete vegetation list). A quadrat-by-quadrat visual analysis of changes in plant species and cover classes indicated that species composition and aerial cover were relatively unchanged across the years. Visual estimations of cover introduce an unknown level of observer bias (Hope-Simpson 1940, Greig-Smith 1983, Hatton et al. 1986, Kennedy and Addison 1987, Lepš and Hadincová 1992). In addition, where the observer is standing when she records cover class can also influence interpretation because it is often impossible to see the entire quadrat from one spot, especially in forest and shrub plots. Therefore, changes of less than or equal to two cover classes across all years were only cursorily examined, and in all cases changes were largely attributed to observer variability. Thirty-two out of 952 records including 17 unique plant species had changes equal to or greater than three cover classes across all years (Table 10), and these were examined more closely.

Table 10. Large cover class changes (> 2) at BBC-52 quadrats across all years.

The numbers under each year column represent the recorded cover class and 'diff' is the difference in cover class across all years. The cover classes were from 0 to 6 and represented the following percent areal cover: 0 to <0.5, 0.5 to 5, 6 to 25, 26 to 50, 51 to 95, and 96 to 100.

Quadrat	Scientific Name	Common Name	2000	2002	2004	2006	2008	2010	Diff
T2D	<i>Acer circinatum</i>	vine-maple	0		1	1	3	2	3
T6B	<i>Acer circinatum</i>	vine-maple	2	2	1	4	3	3	3
T4B	<i>Athyrium filix-femina</i>	lady fern	0	2	1	2	1	3	3
T1C	<i>Carex spp.</i>	sedge		0	2	4	0	3	4
T2D	<i>Gaultheria shallon</i>	salal	2	0	1	1	3	2	3
T4G	<i>Gaultheria shallon</i>	salal	3	3	2	5	4	4	3
T1C	<i>Juncus supiniiformis</i>	spreading rush	1	3	6	5	5	5	5
T4B	<i>Juncus supiniiformis</i>	spreading rush		5	0	0			5
T6F	<i>Juncus supiniiformis</i>	spreading rush	0	0	4	5	2	1	5
T2C	<i>Juncus supiniiformis</i>	spreading rush	1	3	5	4	4	1	4
T4E	<i>Juncus supiniiformis</i>	spreading rush	2	4	4	3	1	5	4
T5G	<i>Juncus supiniiformis</i>	spreading rush	2	3	3	5	4	4	3
T6G	<i>Juncus supiniiformis</i>	spreading rush	2	3	5	4	4	5	3
T5G	<i>Ledum groenlandicum</i>	Labrador tea	4	4	4	5	4	2	3
T6G	<i>Ledum groenlandicum</i>	Labrador tea	4	4	1	3	2	2	3
T5D	<i>Malus fusca</i>	W. crabapple	2		2	3	3	0	3
T4C	<i>Nuphar luteum</i>	yellow pond lily	2	2	0	3	2	2	3
T6E	<i>Nuphar luteum</i>	yellow pond lily	5	3	3	5	2	3	3
T4G	<i>Polystichum munitum</i>	sword fern	3	1	1	1	1	0	3
T6I	<i>Pseudotsuga menziesii</i>	Douglas-fir	2	2	2	0	3		3
T4E	<i>Pteridium aquilinum</i>	bracken fern	3	1	1	2	0	1	3
T1D	<i>Rhamnus purshiana</i>	cascara		1	2	1	4	1	3
T2D	<i>Rubus spectabilis</i>	salmonberry	0	1	1	2	2	6	6
T5G	<i>Salix spp.</i>	willow	3	1	0		1	0	3
T3D	<i>Sparganium spp</i>	burreed			0	0	3		3
T2B	<i>Spirea douglasii</i>	hardhack	3	2	2	5	5	3	3
T5G	<i>Spirea douglasii</i>	hardhack	3	3	4	5	2	2	3
T6D	<i>Spirea douglasii</i>	hardhack	5	4	3	4	3	2	3
T6G	<i>Spirea douglasii</i>	hardhack	5	5	3	3	3	2	3
T5I	<i>Tsuga heterophylla</i>	W. hemlock	5	4	4	3	3	1	4
T4A	<i>Tsuga heterophylla</i>	W. hemlock	3	4	4	5	6	3	3
T5B	<i>Tsuga heterophylla</i>	W. hemlock		0	2	1	3	1	3

Spreading rush (*Juncus supiniiformis*) had seven instances where the recorded cover class differed by at least three categories across all years. This species dies back every year and annual biomass production can vary greatly based on weather and other natural conditions. Yellow pond lily (*Nuphar luteum*) and burreed (*Sparganium spp*) may also have great annual variability. For the other species shown in Table 10, there were not any consistent trends that would suggest a shift in vegetation from predevelopment (2000-2004) to construction (2006-2010) periods.

Aggregating the average number of species per quadrat by strata type (forest, shrub, or herbaceous) indicated that there was no change between predevelopment baseline conditions (2000-2004) to construction conditions (2006-2010) (Figure 12).

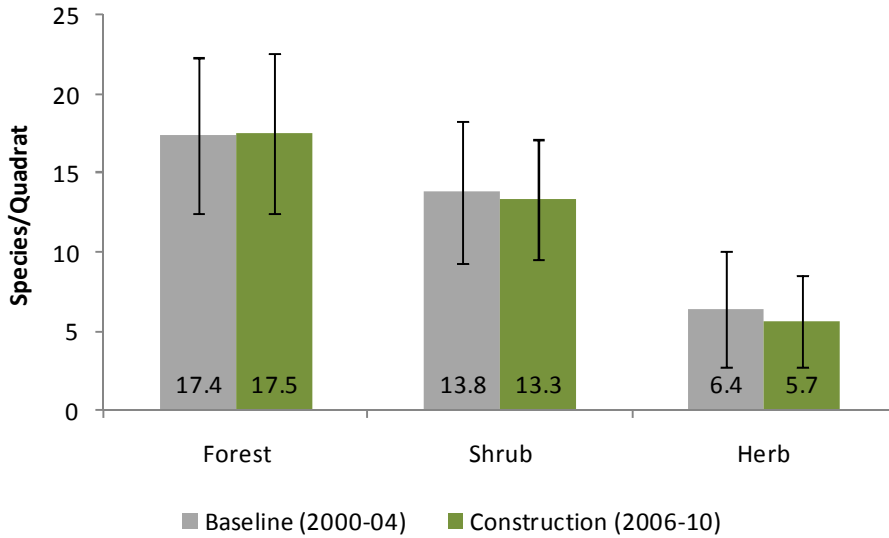


Figure 12. Species per strata for baseline and construction periods at BBC-52.

The bars represent that average number of vascular plants at each quadrat aggregated by forest, shrub, or herbaceous strata. The error bars are plus or minus one standard deviation.

The Redmond Ridge monitoring plan (King County 1999) identified 8 invasive species that were to be monitored (Table 11). An additional 2 species (English holly and European mountain ash) were present in the monitored quadrats and were added for consideration. Of these 10 total species, 6 were omitted from further analysis: 3 species (hardhack, soft rush⁴⁰, and common cattail) are native and naturally spread aggressively (Hitchcock and Cronquist 1973, Pojar and MacKinnon 1994, Cooke 1997) regardless of development, and 3 species (purple loosestrife, climbing nightshade, and Himalayan blackberry) were not observed in any of the BBC-52 quadrats in any year. For the 4 remaining species (evergreen blackberry, English holly, European mountain ash, and reed canarygrass [RCG]), none had increases in aerial cover where they previously existed, and only RCG appeared to be noticeably spreading over time with new observations during the construction period at quadrats along transects 4, 5, and 6 (Figure 13, and Appendix G).

⁴⁰ Soft rush (*Juncus effusus*) has two native subspecies found on the West Coast of North America (Zika 2003). However, it also has non-native subspecies. It is very difficult to distinguish the varieties in the field and no attempt was made for this project.

Table 11. BBC-52 invasive species.

Eight species were identified in the Redmond Ridge monitoring plan (King County 1999) and an additional two (English holly and European mountain ash) were added for consideration.

Scientific Name	Common Name	KC Weed Status
<i>Lythrum salicaria</i>	purple loosestrife	Class B
<i>Solanum dulcamara</i>	climbing nightshade	Weed of concern
<i>Phalaris arundinacea</i>	reed canarygrass	Non-Regulated Noxious Weed
<i>Rubus discolor</i>	Himalayan blackberry	Non-Regulated Noxious Weed
<i>Rubus laciniatus</i>	evergreen blackberry	Non-Regulated Noxious Weed
<i>Ilex aquifolium</i>	English holly	Weed of concern
<i>Sorbus aucuparia</i>	European mountain ash	Weed of concern
<i>Spirea douglasii</i>	hardhack	None (native)
<i>Juncus effusus</i>	soft rush	None (native)
<i>Typha latifolia</i>	common cattail	None (native)

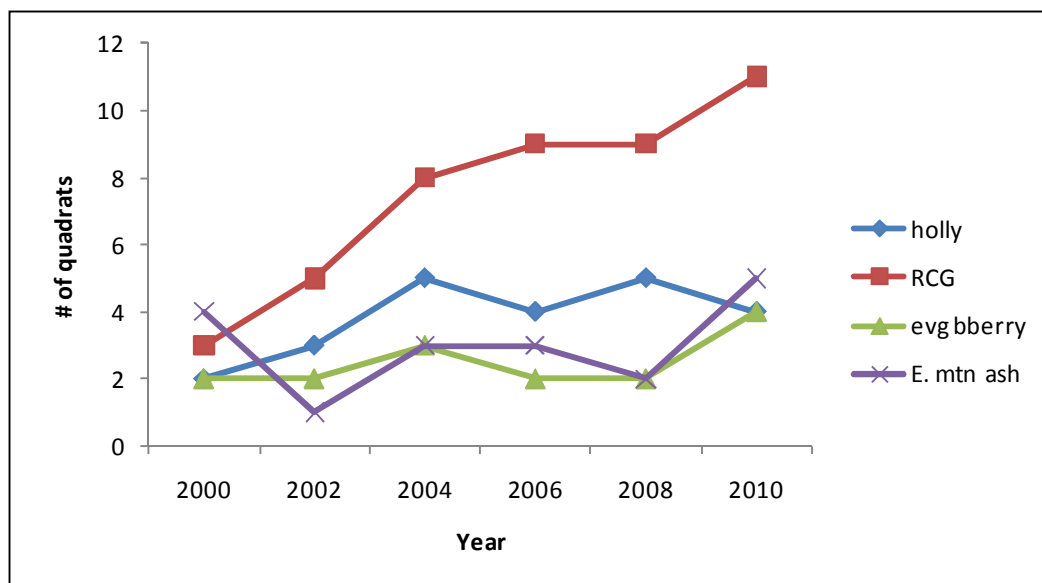


Figure 13. Frequency of invasive species observed in BBC-52.

RCG = reed canarygrass, evg bberry = evergreen blackberry, and E. mtn ash = European mountain ash.

Threshold Exceedance Criteria and Evaluation

Vegetation threshold exceedance criteria were violated if previously undocumented invasive species were introduced, percent cover increased from baseline for a given invasive species, or there was a 20 percent decrease in species richness within any of the vegetation community types. None of these criteria were exceeded although RCG does seem to be expanding southward. However, RCG was present prior to UPD development and once established its spread can be difficult if not impossible to stop. Where found, its aerial cover tends to be relatively low (usually below 5 percent with the exception of values up to 75 percent at quadrat T5C). Because RCG seeds no longer germinate after 48 months of inundation (Comes et al. 1978), RCG spread by seed should be limited in the permanent open-waters of BBC-52.

Corrective Actions

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

3.6 Stream Channel Stability (Stream Cross-Sections)

In streams, increases in peak discharge and duration of high flows often result from increases in impervious area related to urbanization and can increase sediment transport and destabilize stream channels (Booth 1990). UPD planning involved extensive stormwater modeling, and 58 stormwater ponds (30 at Redmond Ridge; 28 at Trilogy) were constructed to minimize impacts of increased impervious area. Regularly taking measurements of stream cross-section dimensions in 7 streams at 2 to 5 locations per stream facilitates tracking changes in channel shape over time. The 7 streams include Colin North, Colin South, Adair, Wallace, Mackey, Evans Central, and Rutherford Creeks. Wallace Creek cross-sections were measured in 2008, Adair Creek cross-sections were measured in 2009 and cross-sections at all 7 streams were measured in 2010 (Figure 14).

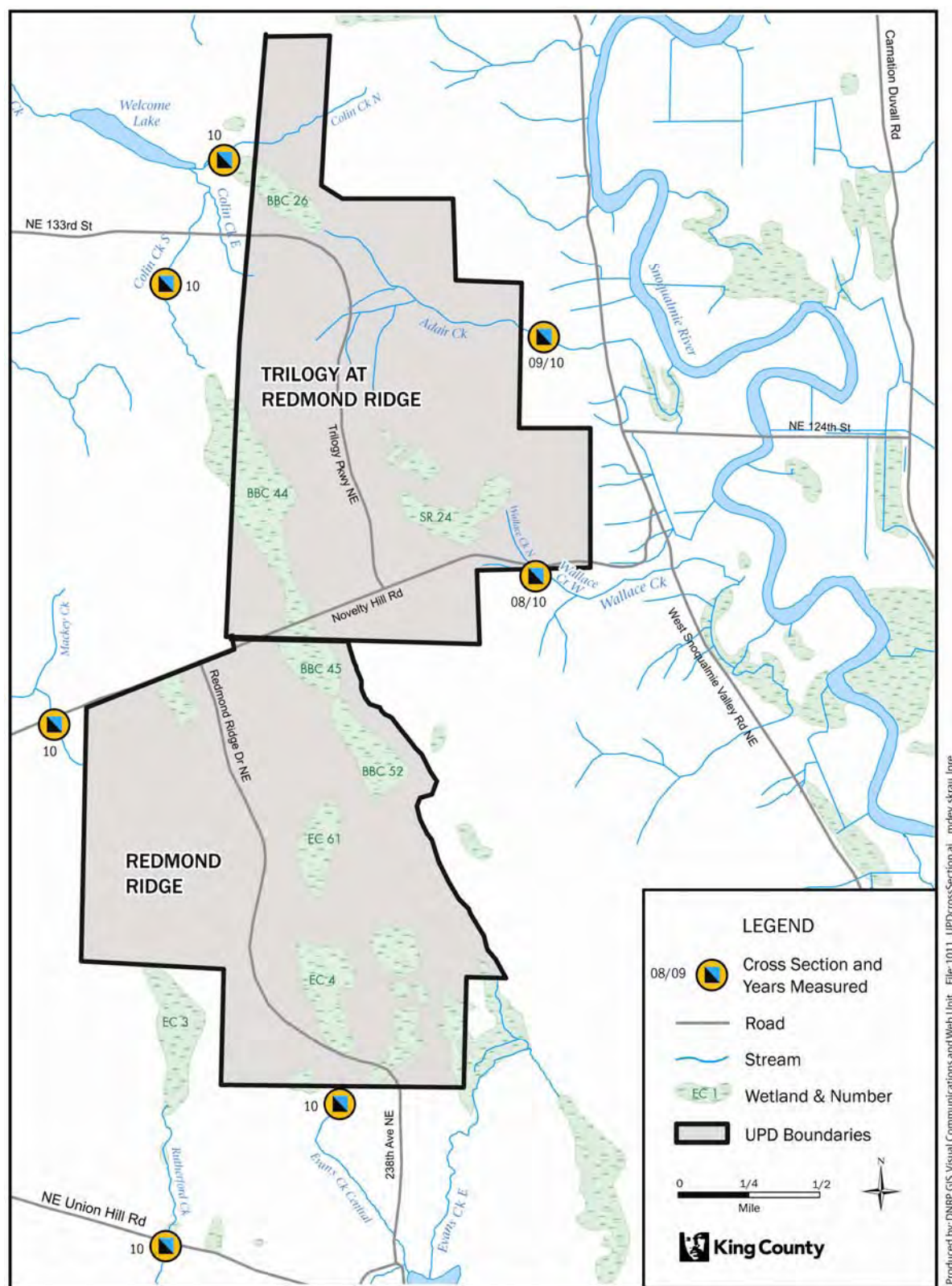


Figure 14. Approximate location of stream cross-section measurements. Cross-section dimensions were measured in 2008, 2009, and 2010 at various stream locations. Two to five cross-sections are spaced over a 16.8 to 49 m (55- to 161-ft) reach within the vicinity of the symbol shown.

Modifications

Beginning in 2007, biennial cross-section measurements were limited to two streams, Wallace and Adair Creeks, with a final site visit prescribed at least seven years after construction start-up at all seven streams [see the 2007 UPD report (King County 2010) for a discussion of the justification for this monitoring change]. The final site visit was made at all sites in 2010.

Sampling Recommendations

Monitoring requirements outlined in the Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) and modified in the 2007 report (King County 2010) have generally been met. No further sampling will be conducted.

Procedures

Field data collection methods from 1991 to 2005 and reintroduced from 2008 to 2010 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 (sometimes referred to as the sag-tape procedure). 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 were calculated using basic trigonometry equations⁴¹. With both methods, bed surface elevation was recorded at locations determined using best professional judgment to capture any significant geomorphic features (e.g., bankfull, thalweg, or edge of water) or any inflection points for a total of approximately 15 to 30 measurements per cross-section. The left bank end point was set at a relative elevation standardized across years, and each cross-section was compared graphically to all previous years to see if the stream channel cross-section changed over time. In addition, the thalweg depth was compared across years to determine whether the depth threshold criteria were exceeded. Because of the discrepancy in results based on the change in methods, data collected in 2006 and 2007 were excluded from analysis.

Results

Stream cross-sections were visited and measured at up to 7 streams in 1991 to 1993, 1998 to 2002, and 2005 to 2010⁴². All stream channel geometry survey results were analyzed graphically, but locations where post-development thalweg depths changed from average predevelopment depths more than the threshold exceedance criteria (13 cm Trilogy, 8 cm Redmond Ridge) were given extra scrutiny. Thalweg depths were relatively consistent across survey years regardless of development status (Table 12), especially at Colin Creek North, Colin Creek South, and Mackey Creek. Results of this graphical analysis are presented by stream in the following sections.

⁴¹ Trigonometry calculations were not required using the tape measure method for data collected during 1991-2005 and 2008-2010.

⁴² As previously mentioned 2006 and 2007 were excluded from analysis due to a change in data collection methods that affected the results.

Table 12. Stream cross-section annual thalweg depth measurements.

Values are in meters and are relative to the left bank permanent marker (typically '10 m'⁴³). Large values represent shallower depths than small values. Bold and underlined values are outside the predevelopment average plus or minus the UPD-specific threshold criterion (13 cm for Trilogy and 8 cm for Redmond Ridge). Blank values indicate no field surveys were conducted.

Stream	Tr #	1991	1992	1993	1998	1999	2000	2001	2002	2005	2008	2009	2010	Pre Avg (m)	Threshold (m)
Adair		Predevelopment								Cons	Post-75% buildout				
	1				8.79	8.82	8.80	8.80	8.85	<u>8.99</u>				8.81	0.13
	2				8.46	8.56	8.54	8.51	8.56	8.64		8.56	<u>8.71</u>	8.53	0.13
	2b	<u>8.81</u>					8.99	9.00	9.02	<u>8.76</u>		8.97		8.95	0.13
	3	8.25	8.22		8.29	8.30	8.28	8.32	8.26	8.27		8.24	<u>8.82</u>	8.27	0.13
Colin N	4				8.57	8.52	8.53	8.56	8.49	8.48		8.47	<u>8.38</u>	8.53	0.13
		Predevelopment								Cons	Post-75% buildout				
	1	8.94	8.94		8.89	8.84	8.89	8.86	8.81	8.82			8.84	8.88	0.13
	2				8.86	8.82	8.80	8.81	8.80	8.82			8.80	8.82	0.13
	3				8.94	8.92	8.93	8.90	8.91	8.92			8.91	8.92	0.13
Colin S	4				8.58	8.56	8.57	8.57	8.56	8.52			8.51	8.57	0.13
		Predevelopment								Cons	Post-75% buildout				
	1				8.40	8.43	8.45		8.46	8.50			8.43	8.43	0.13
	2				8.73	8.70	8.69		8.76	8.75			8.73	8.71	0.13
	3				8.94	8.84	9.03		9.00	8.92			<u>8.76</u>	8.94	0.13
Evans Central	4				9.20	9.21	9.19		9.10	9.11			9.20	9.20	0.13
		Predevelopment								Construction	Post-75% buildout				
	1		9.18	9.19	9.24	<u>9.33</u>	<u>9.34</u>		9.31	<u>9.35</u>			<u>9.49</u>	9.24	0.08
	2		8.59	8.51	8.54	8.59	8.55		8.55	8.56			8.50	8.54	0.08
Mackey	3				8.98	8.97	9.00		8.94	<u>8.85</u>			<u>8.83</u>	8.98	0.08
		Predevelopment								Cons	Post-75% buildout				
	1				8.50	8.51	8.52	8.58	<u>8.60</u>	8.47			<u>8.60</u>	8.51	0.08
Rutherford	2		8.57			8.52	8.52	8.52	8.52	8.53			8.51	8.54	0.08
		Predevelopment								Construction	Post-75% buildout				
	0		9.57	9.54	9.48	9.47	<u>9.44</u>	9.49	9.45	9.57			9.49	9.53	0.08
	1				9.27	9.27	9.25	9.25	9.25	9.25			<u>9.19</u>	9.27	0.08
	2				9.09	9.09	9.02	9.04	<u>9.00</u>	<u>8.98</u>			<u>8.83</u>	9.09	0.08
Wallace	3				8.82	8.81	8.80	8.79	8.74	<u>8.27</u>			<u>8.27</u>	8.81	0.08
		Predevelopment								Cons	Post-75% buildout				
	1		8.05		8.19	8.24	8.24		8.28	8.23	<u>8.36</u>		<u>8.35</u>	8.16	0.13
Wallace	2				7.88	7.89	8.00		7.94	<u>7.56</u>	7.90		7.95	7.92	0.13

Adair Creek

Results from the stream channel geometry surveys at five lateral cross-sections on Adair Creek are presented in Figure 15. The 2010 spring beaver dam breach at the wetland headwaters to Adair Creek and the resulting pulse of water caused extensive changes to the channel shape

⁴³ The left bank permanent markers were not surveyed in for actual elevations. Therefore, '10 m' was select to standardize comparisons over time.

(Figure 15) where measured⁴⁴. However, this dam breach was not linked to UPD development and neither were the resulting changes in stream geomorphology. Prior to 2010, Adair Creek exhibited relatively stable channel shape with little year-to-year variability. Thalweg threshold exceedances were observed in 2005 at cross-section #1 and #2b (Table 12). The results for cross-section #1 show there was up to 18 cm of accretion throughout the channel in 2005. Cross-section #1 was located at a bend in the stream where a very large tree had fallen. These conditions made accurate field measurements extraordinarily difficult. In addition, natural channel-shape changes are often accelerated in areas of bends and large wood. The results for cross-section #2b showed that the channel depth eroded nearly 19 cm in 2005 relative to all years except 1991. However, cross-section #2b exhibited a relatively high degree of year-to-year variability prior to UPD construction. In addition, the right bank marker did not match up between 2005 and 2009; this mismatch suggests a higher level of measurement error than other cross-sections⁴⁵.

⁴⁴ The left bank marker was washed away for transect #1 and #2b making measurements of these transects impossible in 2010.

⁴⁵ Extra slack, twists, or bends in the tape measure stretched across the channel between permanent bank markers could account for right bank markers not matching up in graphical analysis between years. The right bank marker at Adair Creek cross section #2B was moved in 2005 because the original wooden stake disintegrated, but the same marker was utilized in 2005 and 2009.

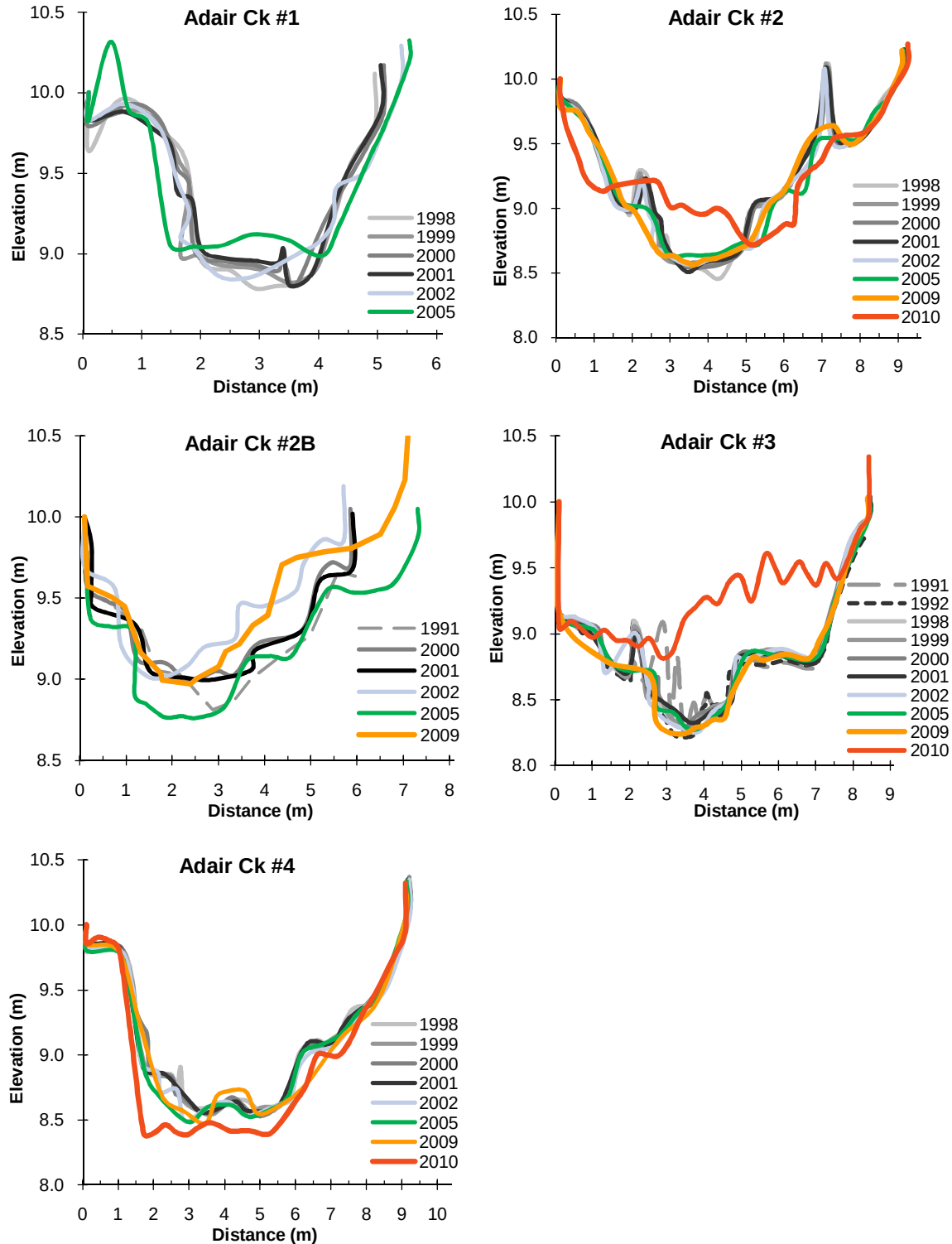


Figure 14. Adair Creek stream cross-sections.

Cross-section #1 was the most downstream cross-section. Line color indicates development status within the subbasin: grays are predevelopment, green is during construction, and oranges are post-75 percent buildout.

Colin Creek North

Results from the stream channel geometry surveys at four lateral cross-sections on Colin Creek North are presented in Figure 16. Thalweg threshold exceedances were never observed (Table 12) and visual inspection of the cross-section survey results confirmed that Colin Creek North had very stable channel shape. The exception to this general stability occurred at cross-section #4 when the location of the thalweg shifted to the right bank between 2002 and 2005 following progressive, though slow, erosion of the right bank. Field notes indicated that some of the right bank erosion was caused by researchers during data collection.

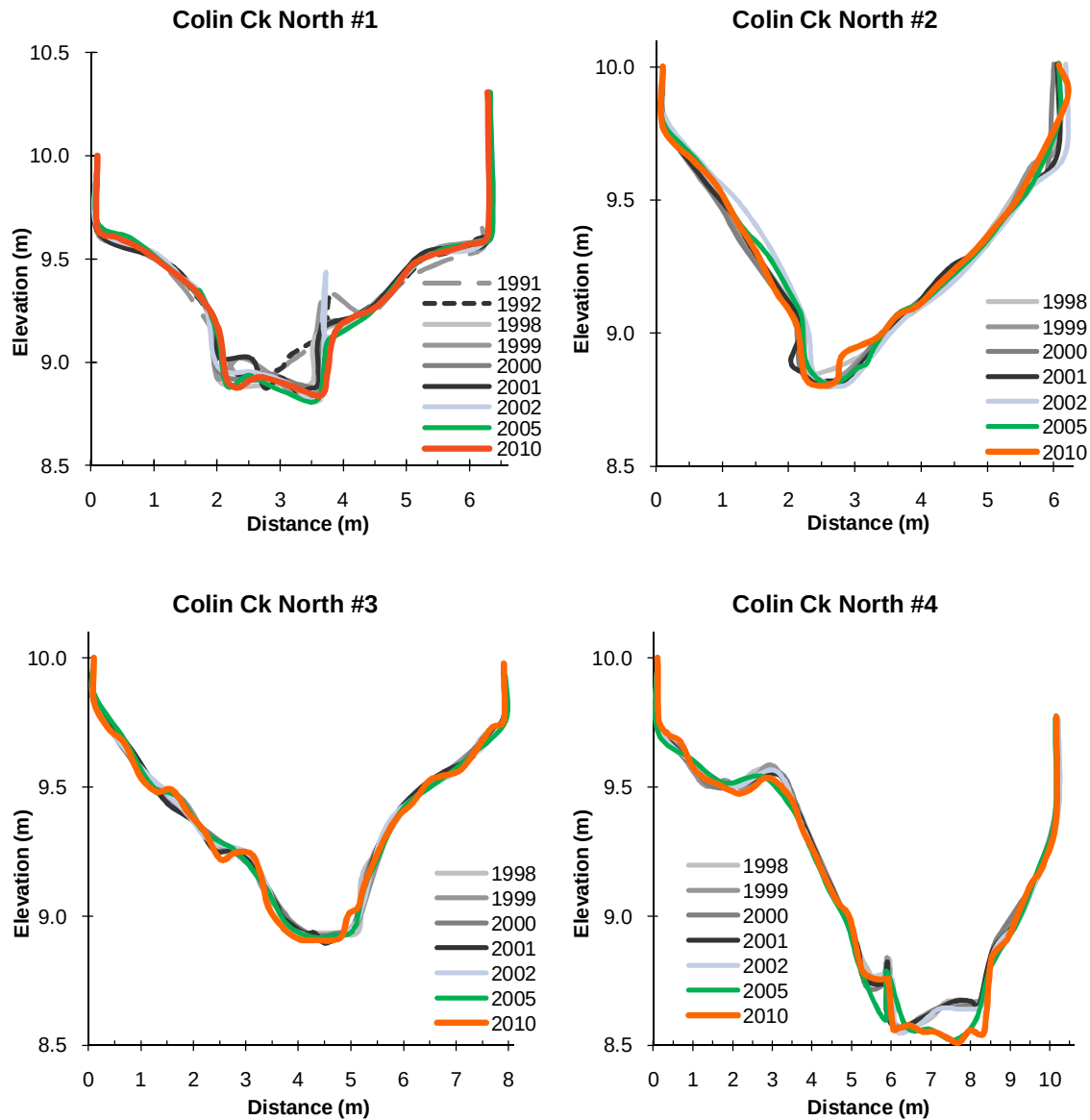


Figure 16. Colin Creek North stream cross-sections.

Cross-section #1 was the most downstream cross-section. Line color indicates development status within the subbasin: grays are predevelopment, green is during construction, and orange is post-75 percent buildout.

Colin Creek South

Results from the stream channel geometry surveys at four lateral cross-sections on Colin Creek South are presented in Figure 17. Thalweg threshold exceedances were only observed one time at cross-section #3 in 2010 (Table 12) and visual inspection of the cross-section survey results confirmed that Colin Creek South had very stable channel shape especially at cross-section #1 and #2. Cross-section #3 had the most variability, with approximately 7 cm of erosion on the right side of a small sand island between 2002 and 2005 and another 13 cm of erosion between 2005 and 2010. The right bank measurements were recorded immediately behind a piece of large wood angled into the wetted channel, and this feature likely accelerated channel migration.

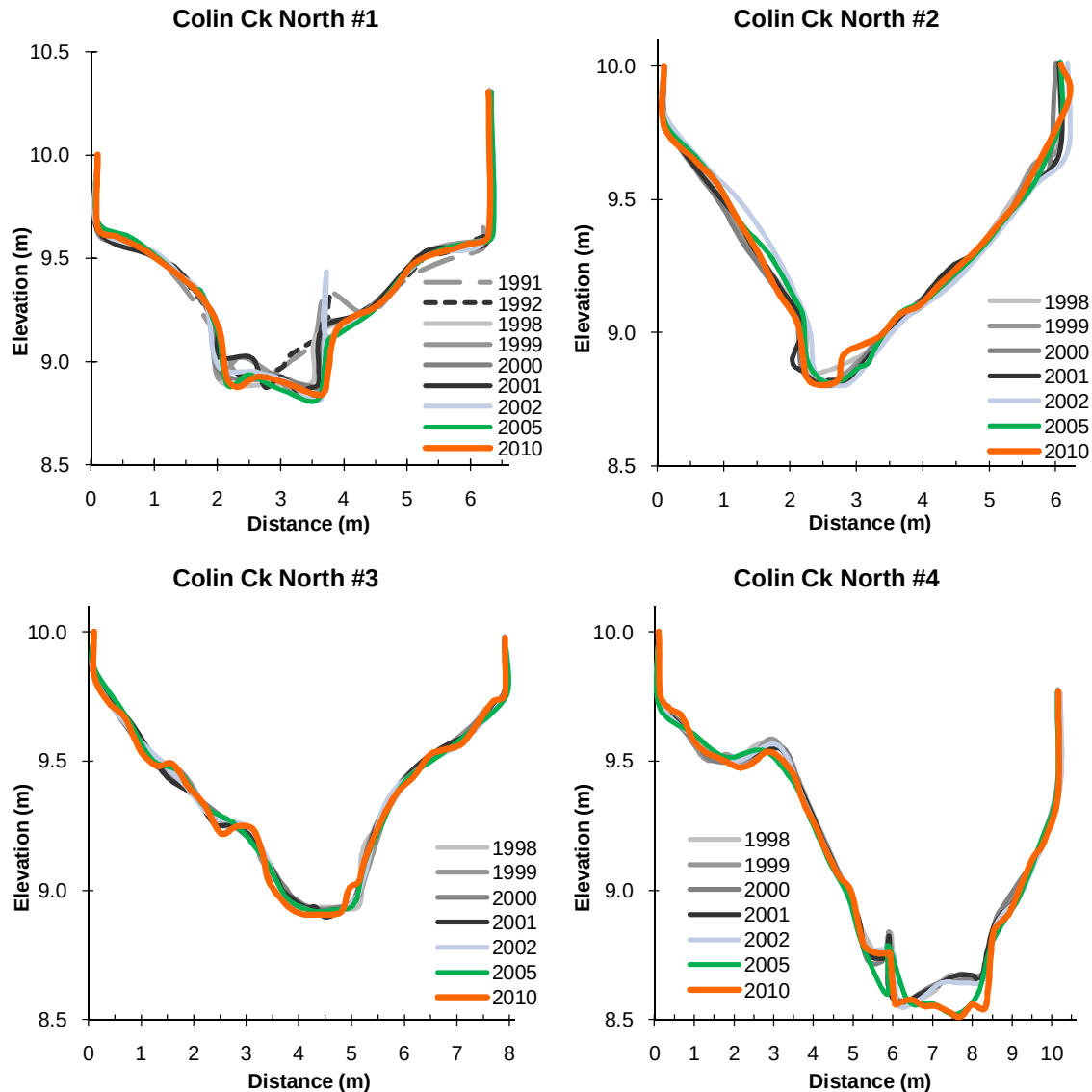


Figure 17. Colin Creek South stream cross-sections.

Cross-section #1 was the most downstream cross-section. Line color indicates development status within the subbasin: grays are predevelopment, green is during construction, and oranges are post-75 percent buildout.

Evans Creek Central

Results from the stream channel geometry surveys at three lateral cross-sections on Evans Creek Central are presented in Figure 18. Thalweg threshold exceedances were observed in 1999, 2000, 2005, and 2010 at cross-section #1 and in 2005 and 2010 at cross-section #3 (Table 12). Visual inspection of the cross-section survey results confirmed that cross-section #2 had very stable channel shape but that cross-sections #1 and #3 were more variable. Cross-section #1 had steady accretion throughout the channel across all survey years regardless of development status. Two of the thalweg exceedances at cross-section #1 were during predevelopment years; these results emphasize the natural variability of this depositional area. In contrast, cross-section #3 had consistent year-to-year erosion centered near the thalweg. Evidence of incising was present from 1998 to 2002, which was prior to UPD development, and may be influenced by the culvert under 235th Place NE approximately 13 m (42.7 ft) downstream of the cross-section.

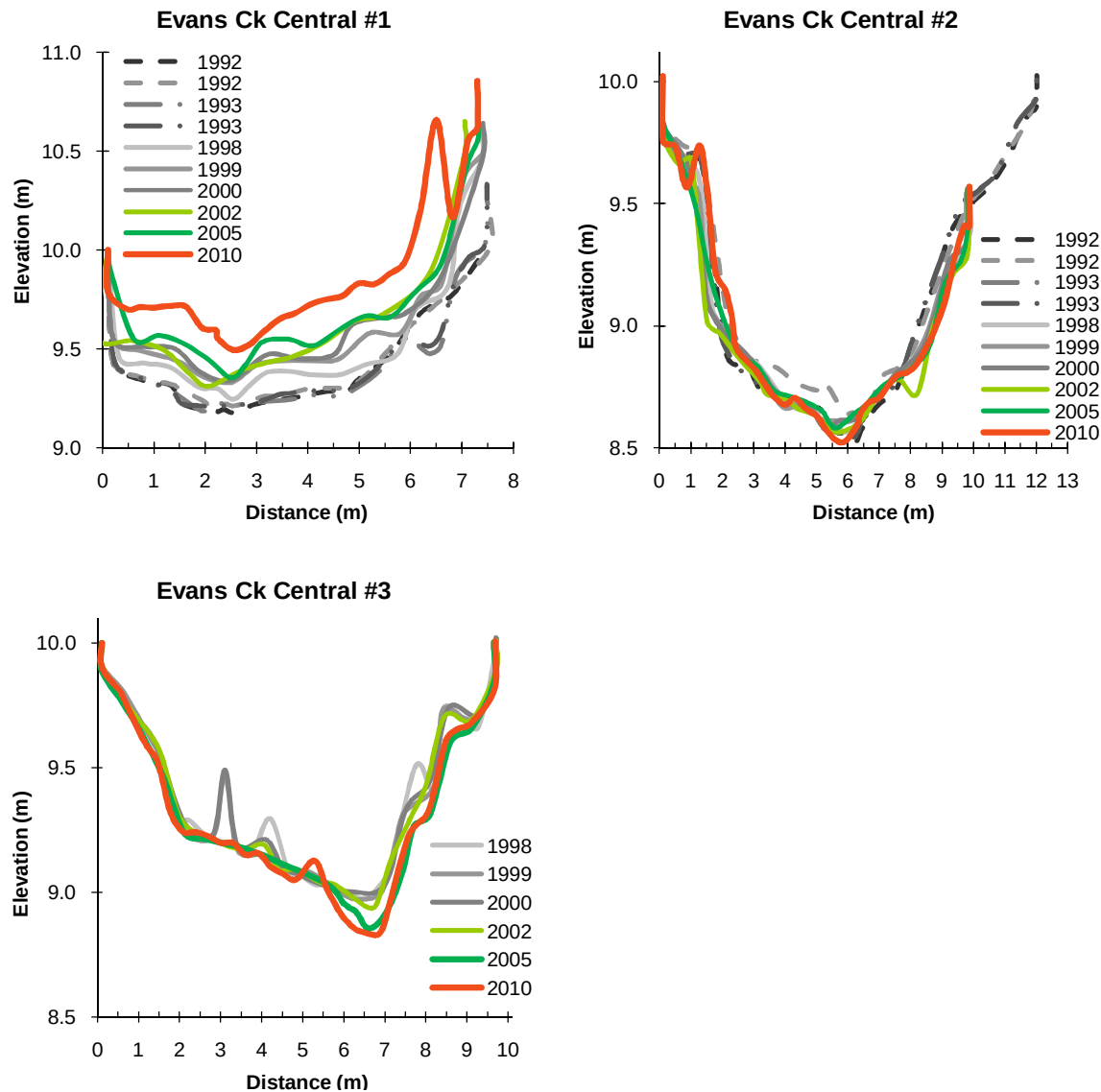


Figure 18. Evans Creek Central stream cross-sections.

Cross-section #1 was the most upstream cross-section. Line color indicates development status within the subbasin: grays are predevelopment, greens are during construction, and oranges are post-75 percent buildout.

Mackey Creek

Results from the stream channel geometry surveys at two lateral cross-sections on Mackey Creek are presented in Figure 19. Thalweg threshold exceedances were observed in 2002 and 2010 at cross-section #1, and no exceedances were observed at cross-section #2 (Table 12). The stream channel geometry surveys were located upstream of Novelty Hill Road where Mackey Creek did not have any known surface flows. Therefore, changes in channel shape were only expected if UPD development changed the hydrology such that surface water flows either persisted or occurred periodically. Visual inspection of the cross-section survey results confirmed that the cross-sections were relatively stable. The 2005 data for cross-section #1 appeared to contain error because the 2010 data returned to the previous patterns. However, the ‘thalweg’⁴⁶ depth changes can likely be attributed to accumulation of leaf litter and other debris in the bottom of a square pit.

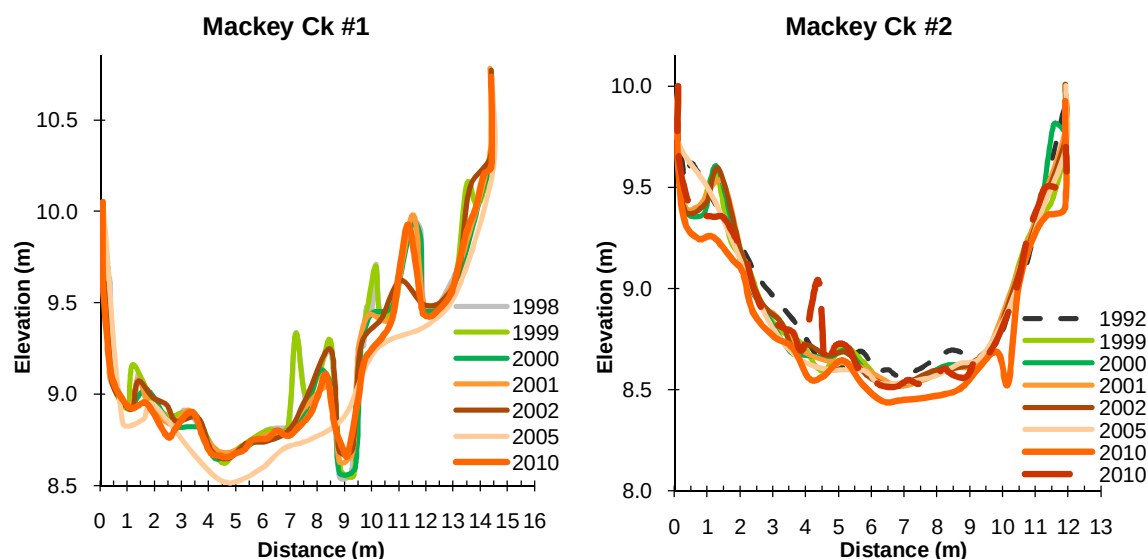


Figure 19. Mackey Creek stream cross-sections.

Cross-section #1 was the most upstream cross-section. Line color indicates development status within the subbasin: grays are predevelopment, greens are during construction, and oranges are post-75 percent buildout.

Rutherford Creek

Results from the stream channel geometry surveys at four lateral cross-sections on Rutherford Creek are presented in Figure 20. Thalweg threshold exceedances were observed at all four cross-sections including once on cross-section #0 (2000), once on cross-section #1 (2010), three times on cross-section #2 (2002, 2005, and 2010), and twice on cross-section #3 (2005 and 2010) (Table 12). Visual inspection of the cross-section survey results confirmed that the cross-sections were variable, except for cross-section #1, which was stable most years with a slight drop (6 cm) in thalweg depth between 2005 and 2010. Cross section #0 showed a high degree of year-to-year variability, including before UPD development. Both the left bank and the thalweg eroded during the predevelopment period between 1992 and 1999, and these trends continued through the subbasin construction period between 2000 and 2002. In 2010, the thalweg location switched from the right side to the left side of the channel. Cross-sections #2 and #3 have been

⁴⁶ Thalweg is written with single quotation marks because thalweg typically refers to the deepest part of a stream or river, but there are no known surface flows within the area surveyed for cross sections on Mackey Creek.

incising throughout the monitored period, including prior to UPD development. Cross-section #2 had the most erosion (15 cm) between 2005 and 2010, whereas cross-section #3 experienced the most erosion (47 cm) between 2002 and 2010.

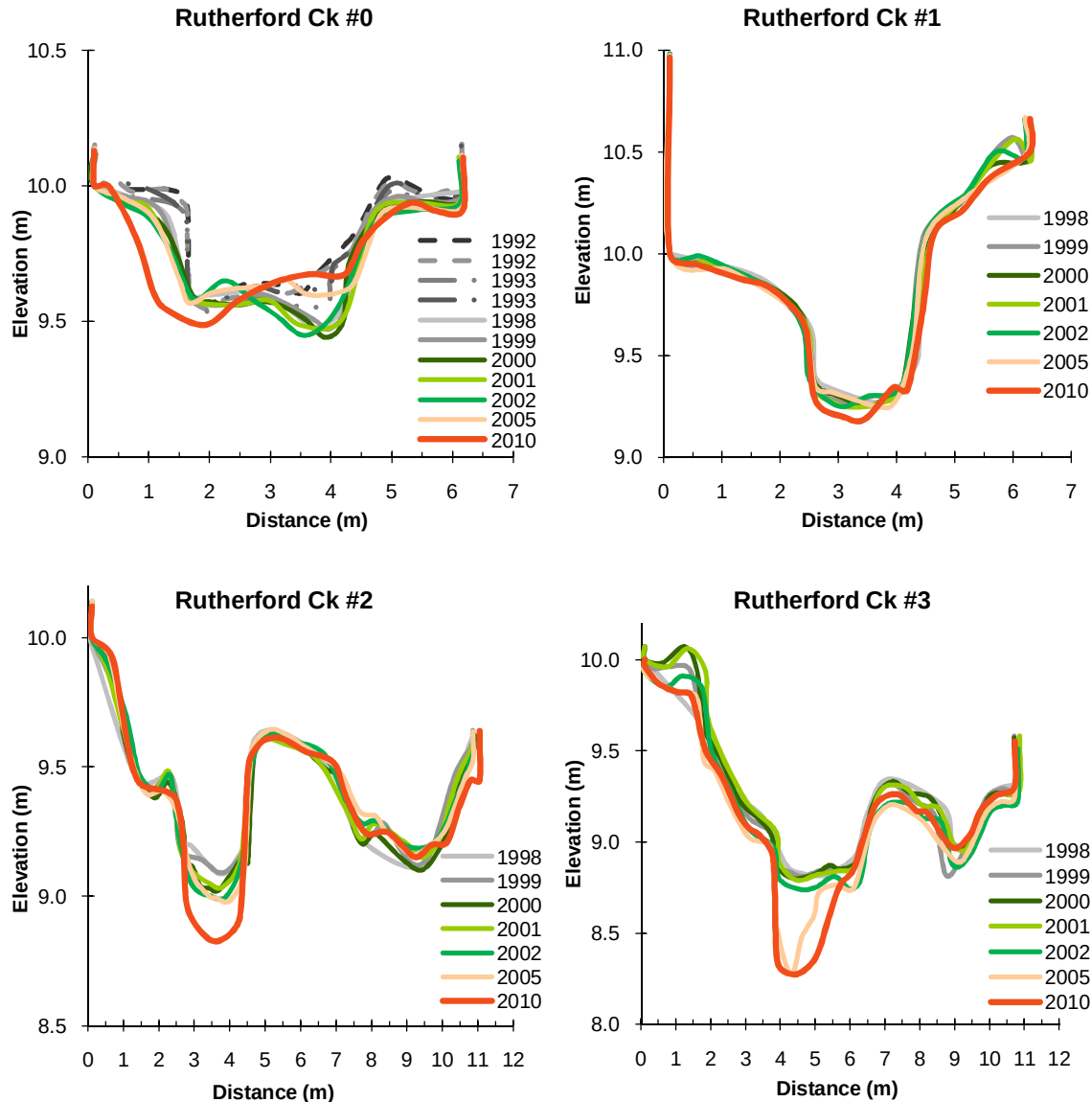


Figure 20. Rutherford Creek stream cross-sections.

Cross-section #0 was the most upstream cross-section. Line color indicates development status within the subbasin: grays are predevelopment, greens are during construction, and oranges are post-75 percent buildout.

Several factors complicate the analysis of the Rutherford Creek stream channel geometry surveys including (1) the placement of the cross-sections adjacent to roads and culverts; (2) the surrounding landuse; and (3) several beaver-dam-induced high flow events. Cross-sections #0 and #1 were located in a short 26 m (85 ft) section between NE Union Hill Road and 225th Avenue NE, and cross-sections #2 and #3 were immediately downstream of the 225th Avenue NE culvert. In addition, there was a non-UPD stormwater pond immediately upstream of NE

Union Hill Road that underwent maintenance work during the monitoring period. The cross-sections were located over 1.6 km (1 mile) downstream of the Redmond Ridge UPD boundary, and this area includes residential and agricultural areas in addition to roads and a natural gas pipeline that was modified heavily during the monitoring period. Finally, there were several documented instances of beaver dam breaches between summer 2002 and spring 2004 that caused periodic peak flow events. None of these complicating factors had anything to do with UPD development. Individually and together these factors make it difficult to isolate the effects of the UPDs on channel shape at Rutherford Creek.

Wallace Creek

Results from the stream channel geometry surveys at two lateral cross-sections on Wallace Creek are presented in Figure 21. Thalweg threshold exceedances were observed in 2008 and 2010 at cross-section #1 and in 2005 at cross-section #2 (Table 12). Visual inspection of the cross-section survey results confirmed that accretion made the channel of cross-section #1 shallower in 2008 and 2010 relative to other years and that except for 2005, the channel shape at cross-section #2 was relatively consistent regardless of development period. A large debris slide occurred in the upper reaches of Wallace Creek in May 2005 following a high-intensity, short-duration storm event. This event was not linked to UPD development; however, the erosive upstream area could affect stream channel geometry.

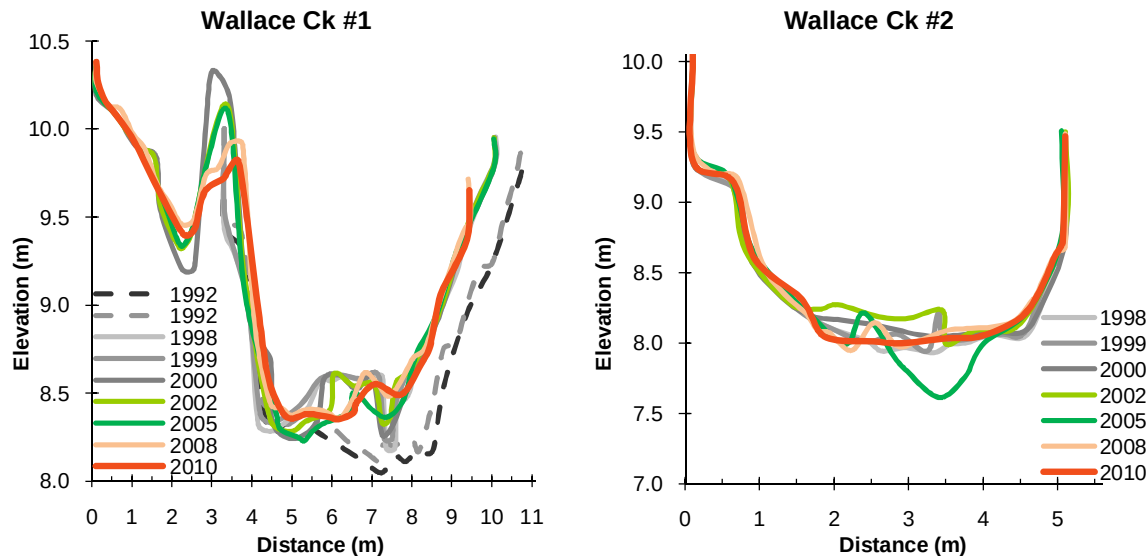


Figure 21. Wallace Creek stream cross-sections.

Cross-section #1 was the most upstream cross-section. Line color indicates development status within the subbasin: grays are predevelopment, greens are during construction, and oranges are post-75 percent buildout.

Sources of Measurement Error

Figure 22 illustrates error by comparing measurements from two cross-sections on Mackey Creek with data collected within the same year. Cross-section #1 was actually measured twice on the same date. No geomorphic changes could have occurred in the completely dry forest floor, yet at the pit located 9 m from the left bank, there was an 8 cm difference in depth. This measurement error matches the threshold exceedance criterion for Redmond Ridge. Cross-section #2 was measured four months apart. Minimal channel shape changes were expected

between these two dates because (1) both were recorded during the summer dry season and (2) the Mackey Creek channel has never been observed with flowing water in the location of the cross-section measurements. However, a 7 cm difference in elevation was recorded across most of the cross-section.

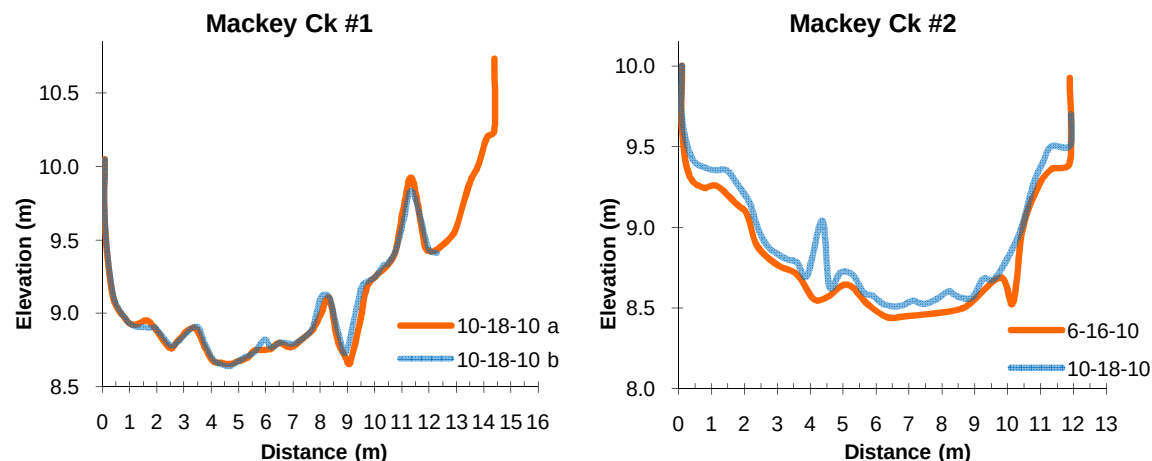


Figure 22. Comparison of same year cross-section measurements at Mackey Creek.

Stream channel geometry survey methods were susceptible to several sources of measurement error that likely affected the results. For example, error between years was likely introduced by slight variations taken in the path across the channel. Measurements of elevation on the top of a rock in one year would be different from the elevation at the base of that same rock taken in another year. Depending on the location of the level and the depth of the channel, the survey rod frequently had to be extended to two, three, or even four lengths. However, the longer the survey rod was extended, the more difficult it was to hold completely vertical, and every degree away from vertical added error to the elevation measurement. At some sample locations, survey crews contributed to changes in the channel geometry by leaving deep footprints in the soft wetland mud adjacent to the channel or by knocking down a portion of a steep, erosive bank. It also was difficult to maintain tension in the measuring tape stretched across the channel, and varying amounts of tension likely led to measurement error in the distance from the left bank permanent monument. Finally, several of the monuments did not remain permanent as intended. Wooden stakes disintegrated and had to be replaced. Between 1993 and 1998 some monuments were never found. Because several monuments consisted of nails in trees, their vertical elevation relative to their original position likely changed. Additionally, some nails became engulfed by the tree bark and lost. Every attempt was made to minimize these potential sources of errors, but an unknown level of measurement error persists.

Threshold Exceedance Criteria and Evaluation

Any changes from predevelopment conditions exceeding the bank erosion and bed erosion or deposition criteria shown in Table 13 violate the thresholds established in the Trilogy and Redmond Ridge monitoring plans and could trigger appropriate corrective actions (King County 1999, 2001).

Table 13. 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)

The bed erosion or deposition criterion was evaluated quantitatively by comparing thalweg depth between years at all cross-section locations (Table 12). Lateral bank erosion and average bed erosion or deposition were evaluated graphically using best professional judgment⁴⁷. The threshold criteria were exceeded frequently (see Table 12, Figures 15-21, and accompanying discussion). However, these exceedances could not be definitively linked to UPD development. In some cases the changes in channel stability reflected a continuation of natural patterns exhibited before UPD development began (e.g., Evans Creek cross-section #1 and Rutherford Creek cross-section #2). In other cases the changes were isolated to only one stream cross-section and the change was not persistent across the stream survey reach (e.g., Colin Creek South cross-section #3). In still other cases, confounding factors related to adjacent culverts, landuse, or extreme debris or flow events unrelated to UPD development made it difficult to isolate UPD impacts (e.g., Evans Creek Central cross-section #3, Rutherford Creek cross-sections #0, 2, and 3, and Wallace Creek cross-section #2). On all remaining cross-sections, there were no obvious progressive trends of erosion or accretion when current and previous survey results were evaluated on a continuum. UPD-related changes in channel stability do not appear to be a significant concern in the seven monitored creeks.

Corrective Actions

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

3.7 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 pH, total alkalinity (acid neutralizing capacity), and hardness values typically found in bogs and bog-like wetlands⁴⁸. 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).

⁴⁷ Quantitative analysis of the lateral bank erosion and average bed erosion or deposition criteria rely on interpolation of data between measured points and this method introduces additional error. Visual analysis of graphs was deemed sufficient for the purposes of this report.

⁴⁸ 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.

Three distinct water quality monitoring regimes have been conducted on the UPDs through 2010: (1) January through April sampling beginning in 2002 at 13 wetland and seven stream locations (Figure 23), (2) continuous sampling of stream temperature at five stream gage locations, and (3) summer/fall wetland sampling beginning in 2009 at BBC-45 and BBC-52.

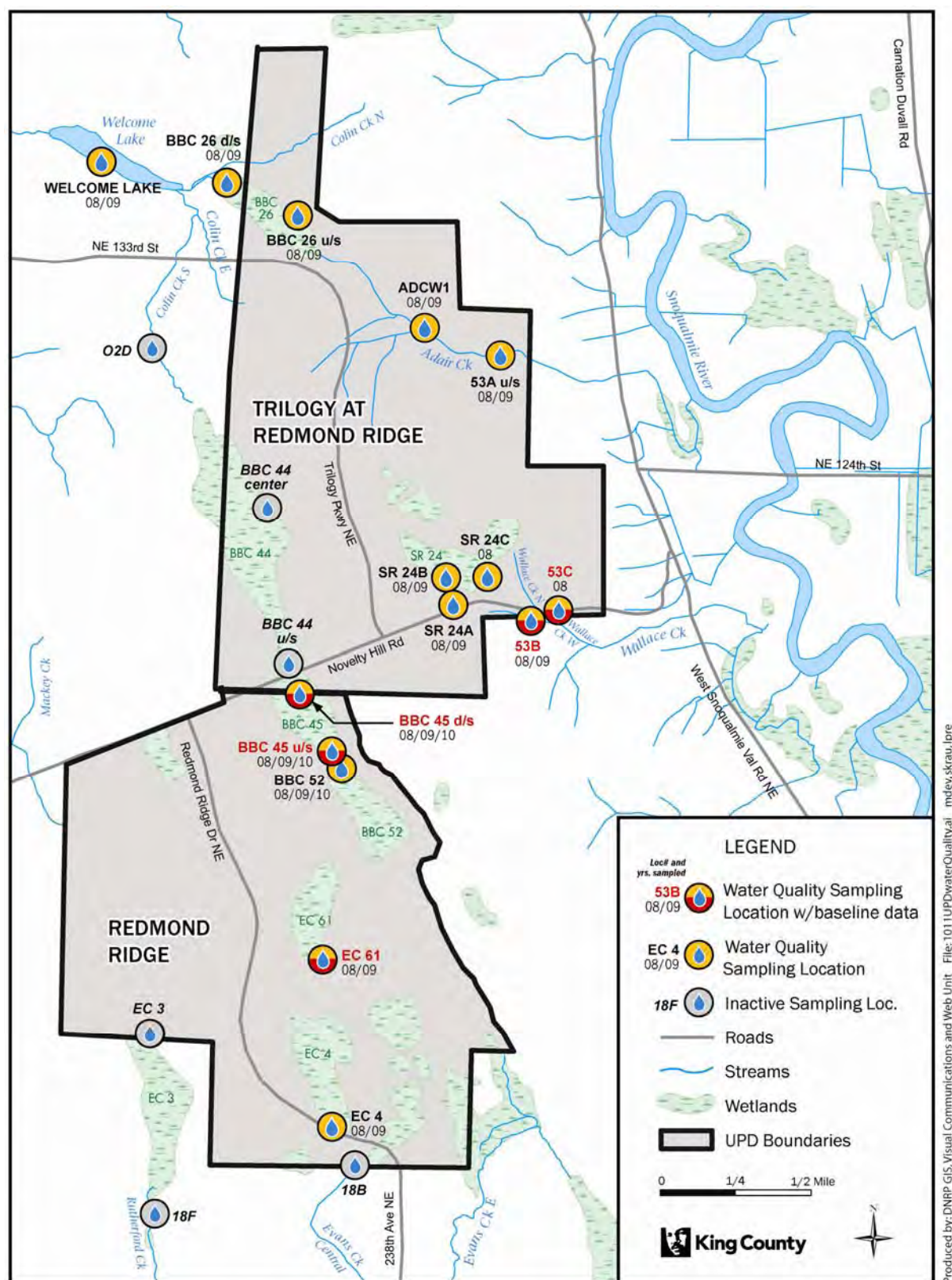


Figure 23. Location of 20 January through April water quality sampling stations. Sampling includes 7 streams and 13 wetlands. "Inactive" sampling locations were last sampled in 2007.

Modifications

The Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) detailed four different sampling requirements related to stream and wetland water quality referred to in the 2007 UPD monitoring report (King County 2010) as Trilogy wetlands, Trilogy streams, Redmond Ridge streams, and Redmond Ridge wetlands. These four requirements were implemented as three distinct water quality monitoring regimes, discussed below under procedures. No modifications have been made since 2007, although the Redmond Ridge wetland sampling was initiated in 2009 and is referred to as ‘summer/fall wetland sampling’ in this report.

Sampling Recommendations

Monitoring requirements outlined in the Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) have been met for the three sampling regimes at all sites except BBC-45 and BBC-52, and therefore the remaining streams and wetlands will no longer be sampled. It is recommended that water quality sampling (including January through April and summer/fall wetland sampling) also be concluded at BBC-45 and BBC-52. Within Redmond Ridge, no parcels remain to be developed that will drain to BBC-52. Concurrent development of Redmond Ridge East will complicate detection of Redmond Ridge impacts. In addition, monitoring at other wetlands has been concluded and no impacts have been definitively linked to UPD development.

Procedures

Three distinct water quality monitoring regimes have been conducted on the UPDs through 2010: (1) January through April sampling, (2) continuous sampling, and (3) summer/fall wetland sampling. The procedures for these three programs are discussed below.

January through April Sampling

Water quality sampling was conducted three times annually between January and April beginning in 2002 at 7 streams primarily downstream of the UPDs and 13 onsite wetlands (Figure 23), including a subset of locations where predevelopment baseline data were collected. Sites began being phased out in 2008 based on subbasin buildout: 15 sites were sampled in 2008, 12 sites were sampled in 2009, and three sites were sampled in 2010. Conventional parameters including turbidity, temperature, dissolved oxygen, conductivity, and pH were measured *in situ*, and beginning in 2006, water samples were collected and analyzed for alkalinity, hardness, and total metals concentrations at most sampling locations.

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

Temperature, dissolved oxygen, and conductivity measurements were collected using either a YSI model 85⁴⁹ handheld system or a Hydrolab water quality sonde. Each field probe was 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. Since 2007, pH was measured using a Hydrolab⁵⁰. EM-Reagents color pHast[®] paper 4.0-7.0 range was used from 2002-2006 to measure pH. Reliably measuring pH was challenging in the UPD surface waters because of low hardness and low conductivity. The various probes that were used over the years (e.g., Oakton pHTestr2, Orion model 230Aplus portable pH meter, Hydrolab water quality sonde) consistently produced different results compared to the pH paper despite meeting QA/QC checks against standard solutions⁵¹. Hydrolab measurements were presumed to be more accurate and less subjective than the pH paper, which seemed to consistently underestimate pH. In order to compare data over time, the results from 2002-2006 using pH paper were multiplied by a factor of 1.242, derived from a linear regression of data collected by both methods over a period of time ($r^2 = 0.529$).

Beginning in 2006, water samples were collected in pre-labeled containers for hardness, alkalinity, and total metals concentrations⁵² at some sites. Two bottles were collected at each site and stored on ice until delivery to the EPA-approved King County Environmental Lab (KCEL). Each parameter was analyzed by KCEL using standard operating procedures (King County Environmental Lab 1999, 2003, 2006) and followed strict protocols for sample handling and quality assurance.

Analysis was confined to visually evaluating graphs of data over time because the quantity of predevelopment data was not sufficient to establish the range of natural variability and to do rigorous statistical comparisons. In other words, only qualitative analyses were completed for water quality monitoring.

Continuous Sampling

In addition to the *in situ* sampling described above, continuous temperature gages recorded 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 Creeks⁵³. These gages were visited approximately every 6-8 weeks for data uploading and battery checks.

⁴⁹ In lentic environments, the YSI probe was gently bobbed through the water column below the surface because accurate readings can only be achieved when water moves across the dissolved oxygen probe (YSI Incorporated 1998).

⁵⁰ In contrast, the Midpoint Report (King County 2006) reported the pH paper results.

⁵¹ The discrepancies between probes for stream and wetland pH readings despite consistent pH readings of standard solutions are likely related to the softness and low ionic strength of the water. Unlike the standards, which are very high in dissolved ions, the UPD surface waters are low in dissolved ions.

⁵² 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.

⁵³ The continuous temperature recording devices were removed at Evans Central and Wallace North Creeks in 2004. See Appendix O from the 2007 report (King County 2010) for data from these creeks.

The data were then checked as part of a quality assurance and quality control (QA/QC) program, and the results were posted on the King County Hydrologic Information Center website⁵⁴.

Summer/Fall Wetland Sampling

Beginning in 2009, grab samples were collected twice a year at BBC-45 and BBC-52 during a summer low-flow period and an early fall flush event. Water samples were collected at each site in pre-labeled containers for total phosphorus, total nitrogen, nitrate-nitrite nitrogen ($\text{NO}_2 + \text{NO}_3$), chlorinated herbicides, and organophosphorus pesticides and were stored on ice until delivery to KCEL where they were analyzed using standard operating procedures. The fall flush sampling was triggered by a storm of at least $\frac{1}{2}$ in (1.3 cm) rainfall in less than 24 hours that followed at least 48 hours of dry (antecedent) conditions.

Results

See Appendix D of the 1998-99 University of Washington Monitoring Report (Comings et al. 2000) for a complete reporting of the predevelopment water quality data, Appendix 4.3.1.3 of the Midpoint Report (King County 2006) for 2002-2006 data, and Appendix Q of the 2007 UPD monitoring report (King County 2010) for *in situ* water quality data for each 2007 sampling date. 2008-2010 and future water quality data are available by request from King County.

January through April Sampling

Where possible in the following sections, water quality results from January through April sampling were compared with predevelopment January through April sampling data collected in the same locations. Results also were compared with state water quality standards, where appropriate. Figures were 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 23 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, we refer to specific conductivity, which has been standardized to a temperature of 25°C for comparative purposes.

Conductivity within both the BBC and ECC subbasins has generally remained steady across the years (1991, 2002-2010), despite some year-to-year fluctuations in the ECC subbasin⁵⁵ (Figure 24). In contrast, all other subbasins appeared to exhibit some degree of increase in conductivity relative to predevelopment conditions. The NWD (Colin North) and ECW (Rutherford) subbasins showed the strongest increases. The conductivity in the two BBC-26 wetland locations (NWD subbasin) increased from less than 55 $\mu\text{S}/\text{cm}$ in 2002-2004 to greater

⁵⁴ <http://green.kingcounty.gov/wlr/waterres/hydrology/>

⁵⁵ Where conductivity was recorded using both a hydrolab and an YSI sonde, the average of the two measurements was reported.

than 75 $\mu\text{S}/\text{cm}$ in 2007-2009. Conductivity at the EC-3 wetland (ECW subbasin) was less than 60 $\mu\text{S}/\text{cm}$ prior to 2004, but it varied between 81 and 100 $\mu\text{S}/\text{cm}$ from 2005 to 2007, when measurement ceased. However, these increased wetland conductivity values are within the range of values found in wetlands in nonurban watersheds throughout the region in the 1980s and 1990s (Horner et al. 2001a)⁵⁶.

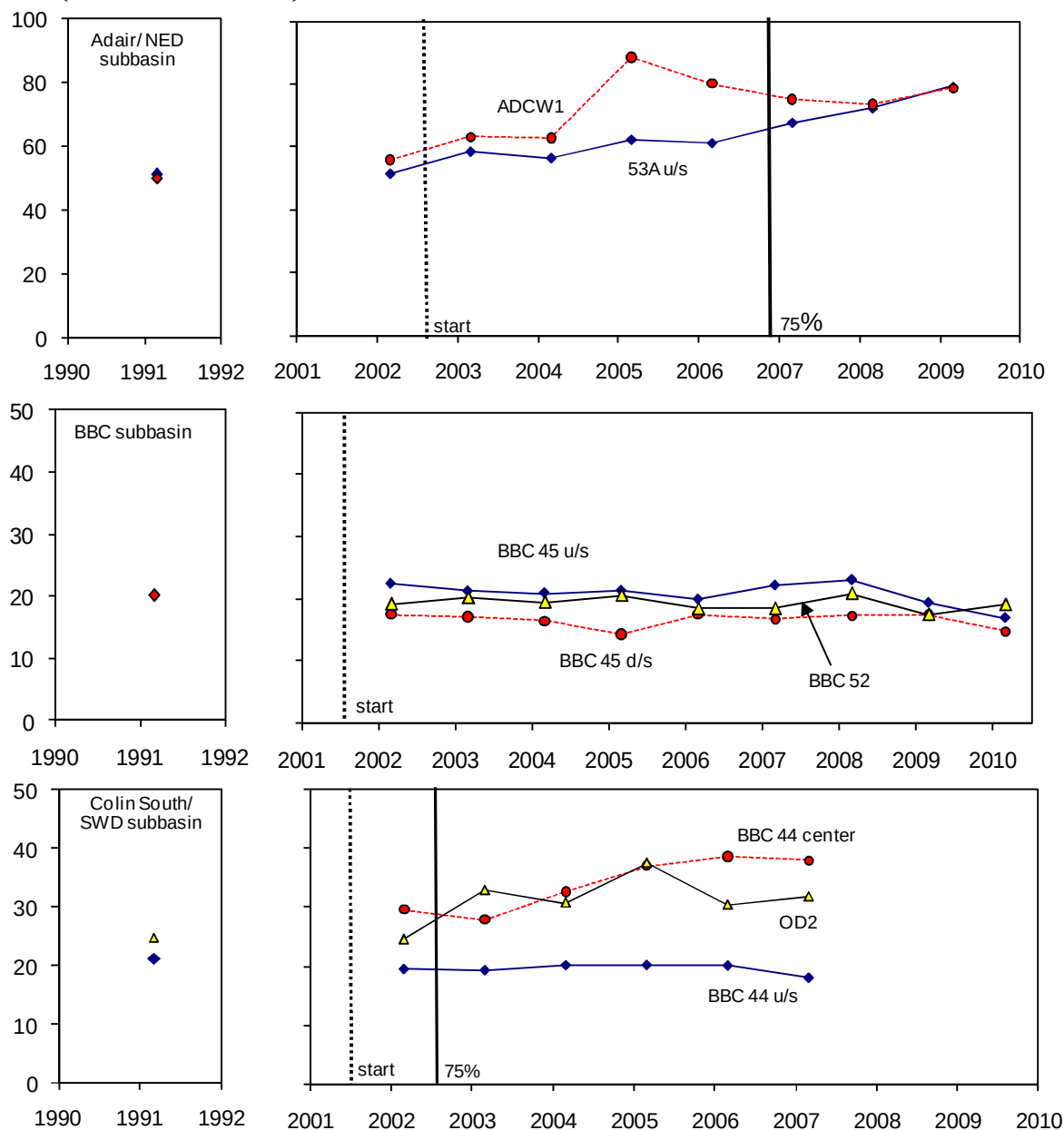


Figure 24. Average annual specific conductivity (1991, 2002-2010).

Data are averages of one to five measurements between January and April each year. Each graph represents a subbasin. Y-axis units are in $\mu\text{S}/\text{cm}$. 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 23 for locations. (Cont'd next page)

⁵⁶ Conductivity of 190 wetlands in nonurban watersheds averaged 72.5 $\mu\text{S}/\text{cm}$ with a median of 46.0 $\mu\text{S}/\text{cm}$ (Horner et al. 2001a).

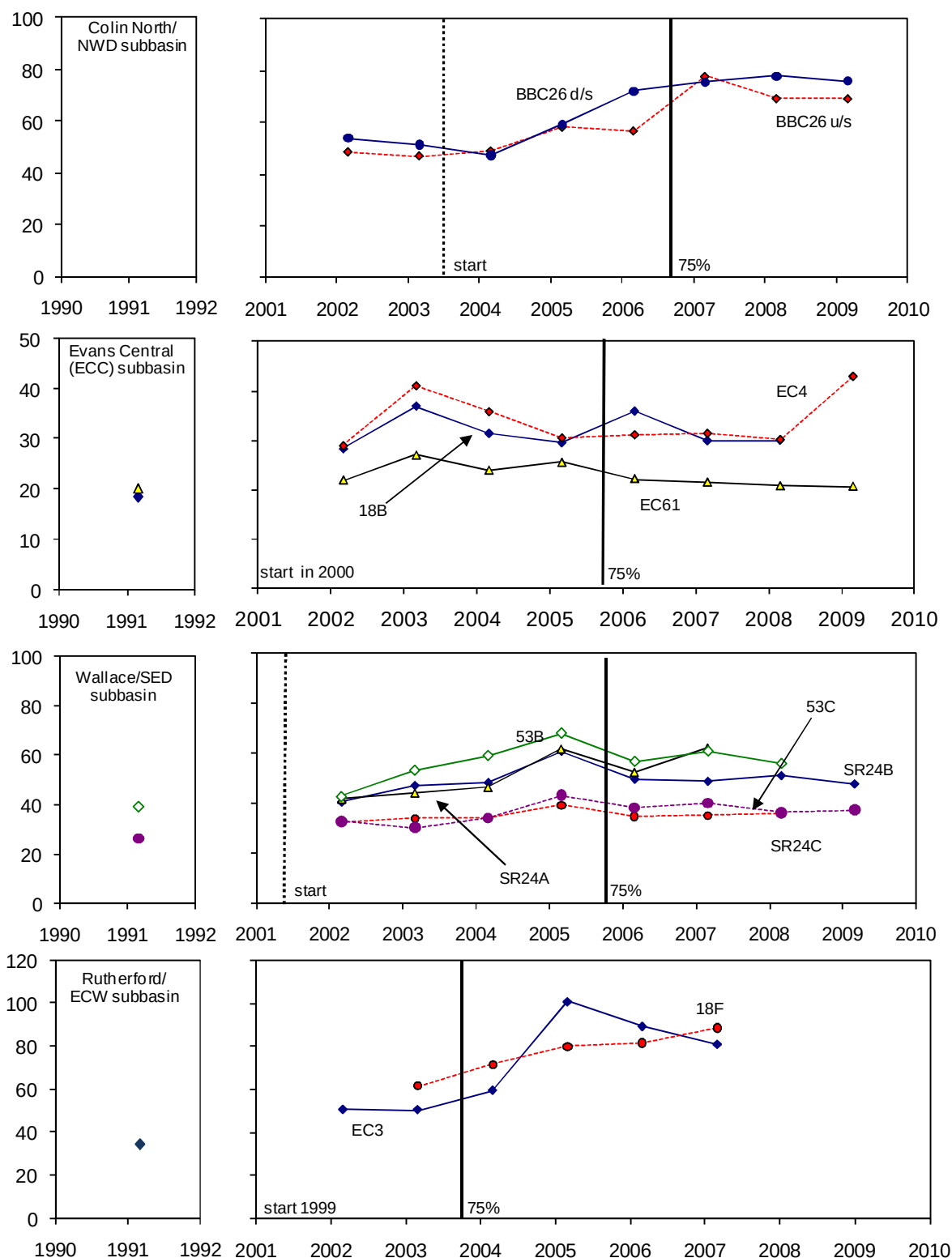


Figure 24 (Cont'd). Average annual specific conductivity.

Temperature

Adverse temperature impacts due to UPD development were not anticipated for area streams or wetlands (Beak Consultants Incorporated 1995), and in fact temperature data for all streams and wetlands showed relatively little change across years for the period of January through April. These measurements hovered around an average of between 5.9 and 8.5°C for all sampling sites except for BBC-26 u/s, which had an average temperature of 10.1°C across all years⁵⁷ (Figure 25). These temperatures were well below state standards of 17.5°C (63.5°F) for salmonid rearing and migration streams⁵⁸ (Washington Department of Ecology 2006). Temperatures were also recorded continuously at several stream gage sites (see ‘Continuous Temperature Sampling’ subsection below).

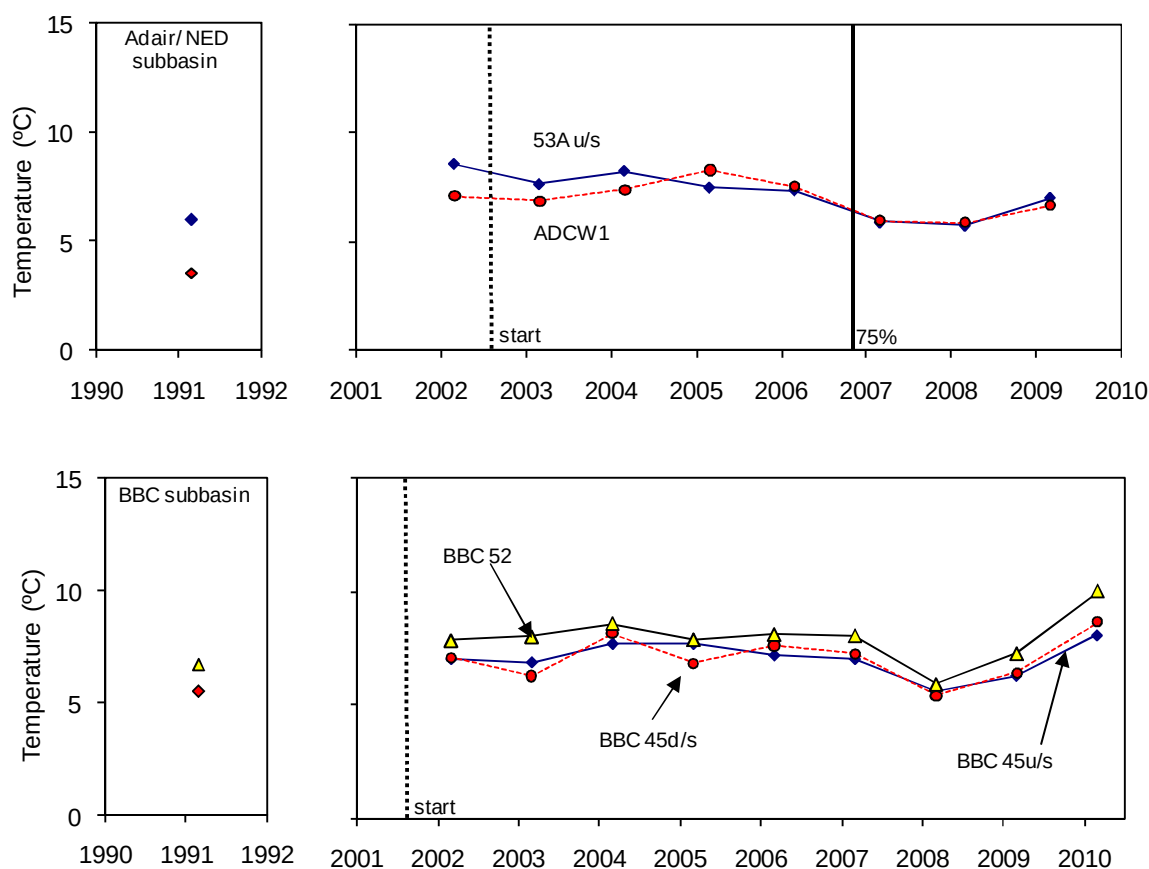


Figure 25. Average annual temperature (1991, 2002-2010).

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 23 for locations. (Cont’d next page)

⁵⁷ 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 was reported.

⁵⁸ State criteria standards are relative to the 7-day average of the daily maximum temperatures. Therefore, continuous temperature data, which are presented in a separate results section, are more appropriate for comparison to state standards.

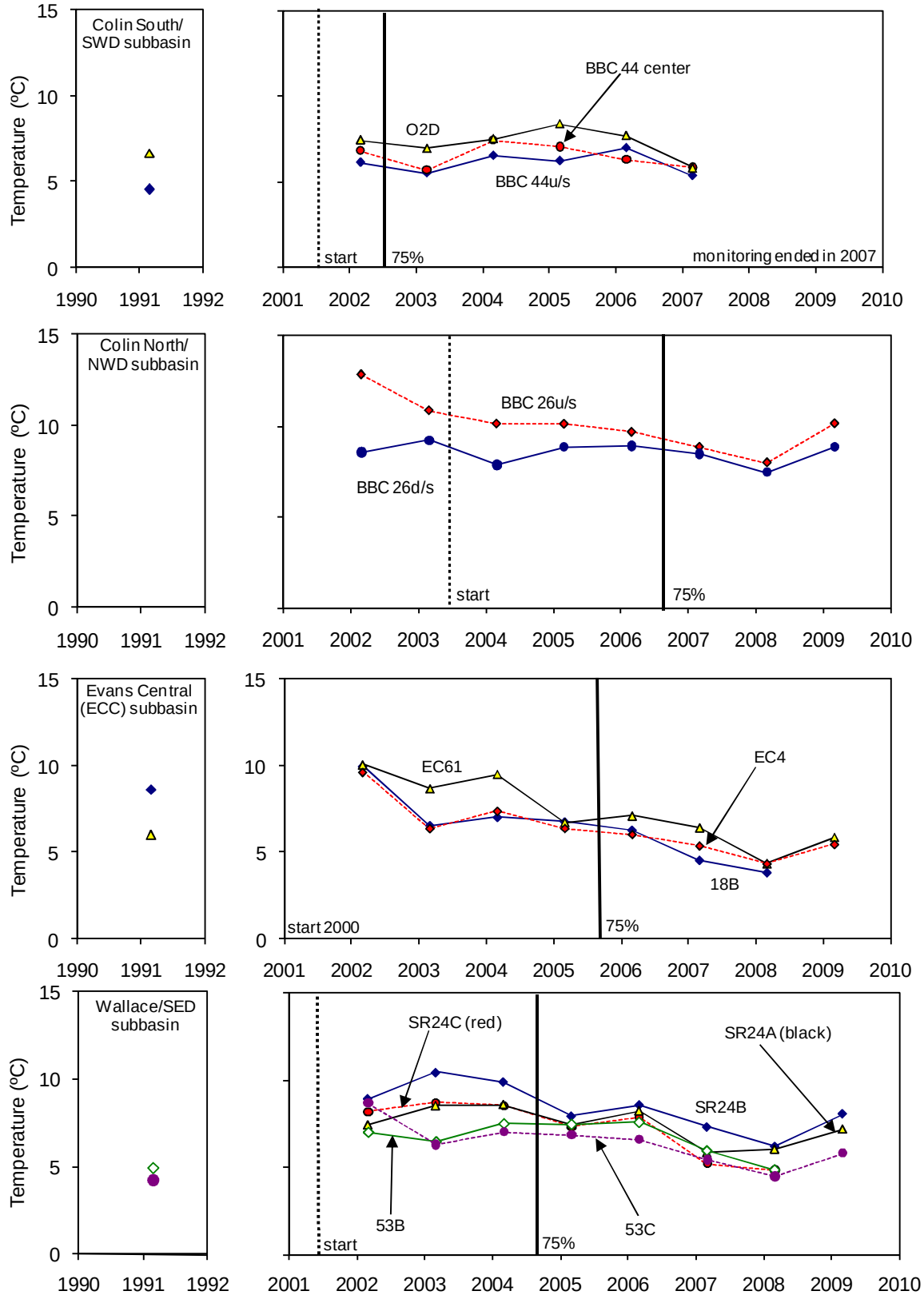


Figure 25 (Cont'd). Average annual temperature. (Continued next page)

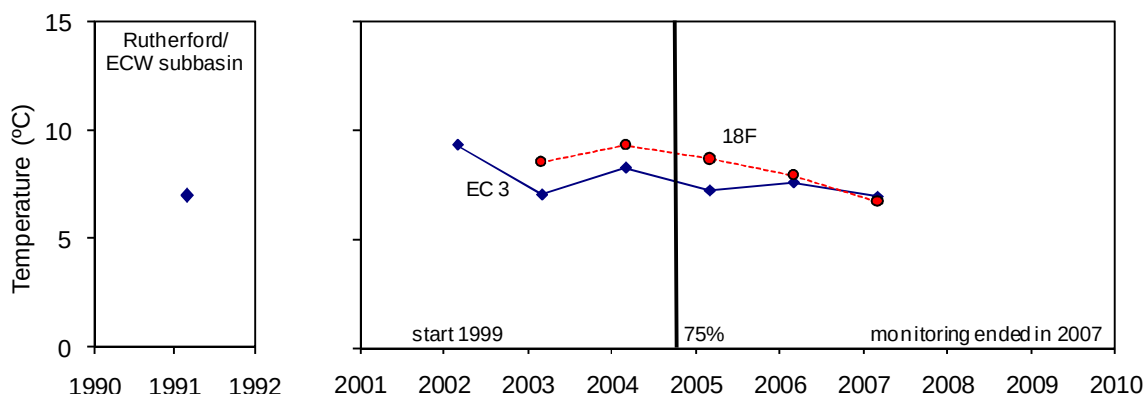


Figure 25 (Cont'd). Average annual temperature.

pH

The 20 monitored streams and wetlands generally all had acidic conditions, with mean winter pH ranging from 4.4 to 7.3 (Figure 26). The mean winter wetland pH values were 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, stream pH values were frequently below the 6.5 to 8.5 state water quality standard for salmonid migration and rearing streams (Washington Department of Ecology 2006) (Table 14). The low pH in these streams is likely a result of the bog or bog-like origin of the wetland headwaters. Overall, the mean pH within each monitored stream and wetland remained consistent across the years. Peaks were typically observed in 2005 (e.g., Wallace Creek – 53B and 53C) or 2006 (most sites), but pH measurements in 2007 to 2010 returned to values observed between 2002 and 2004 (Figure 26). It is notable that the BBC subbasin sites decreased in pH consistently from 2006 to 2010, and it is possible that diversion of surface stormwater away from these wetlands resulting from the construction of stormwater ponds has resulted in the wetlands becoming more bog-like in character.

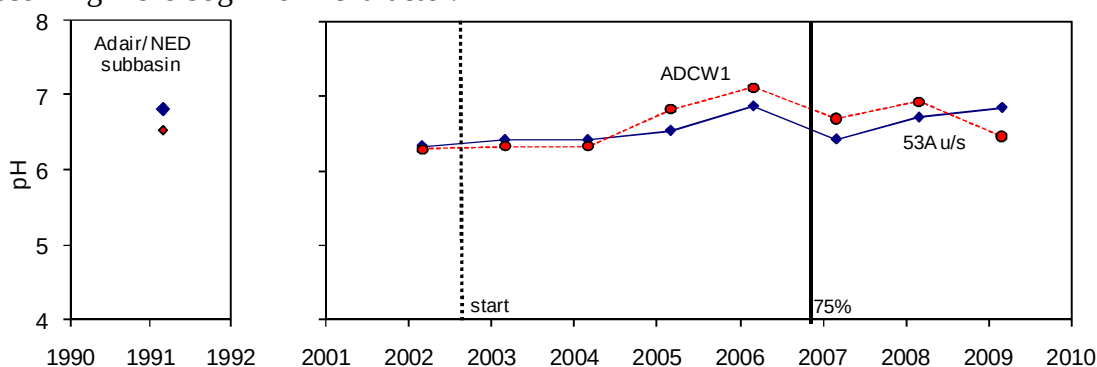


Figure 26. Average annual pH (1991, 2002-2010).

Data are averages of one to five measurements between January and April each year⁵⁹. 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 23 for locations. (Cont'd next page)

⁵⁹ 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). 2007-2010 data were recorded using the Hydrolab.

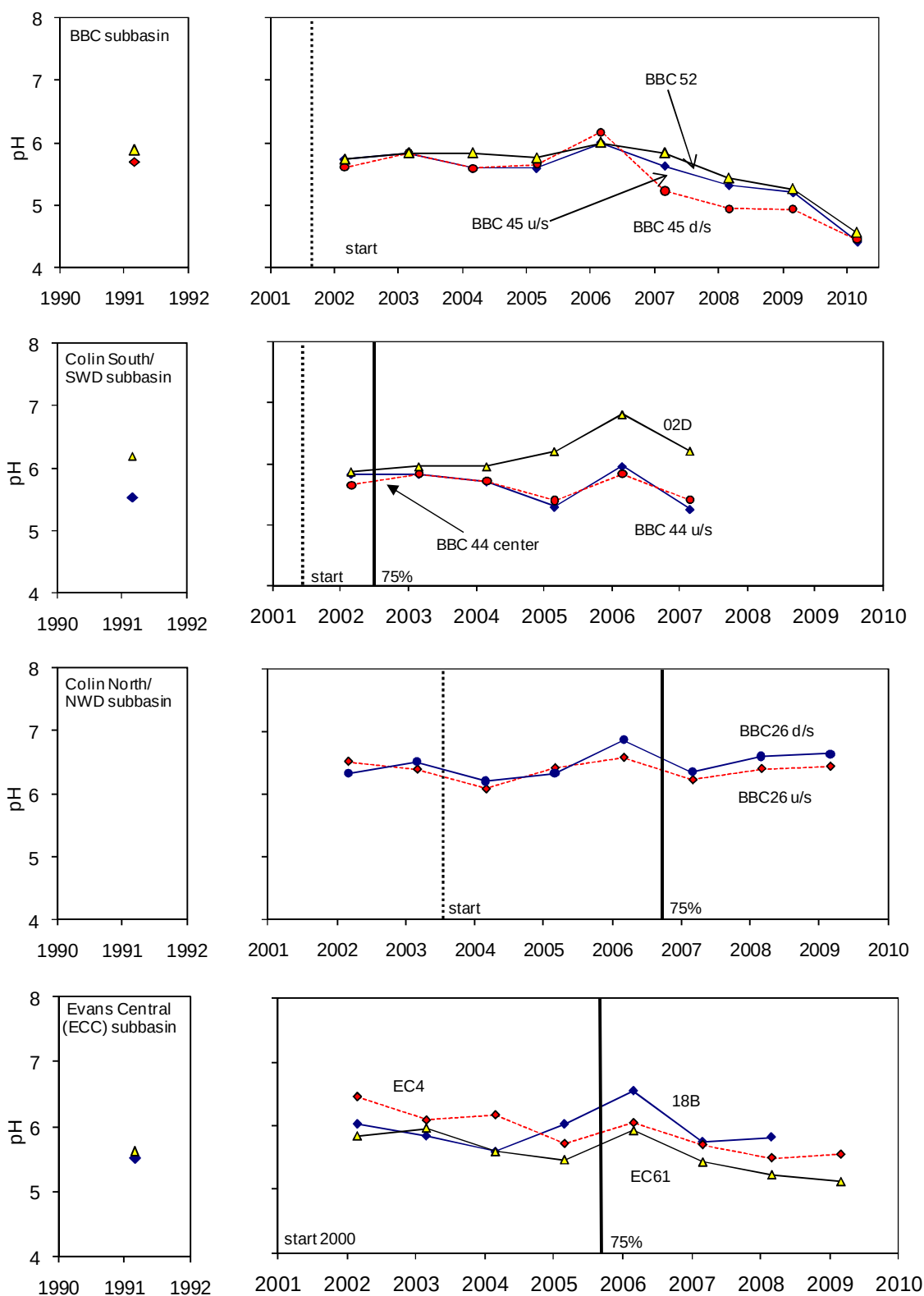


Figure 26. (Cont'd) Average annual pH. (Continued next page)

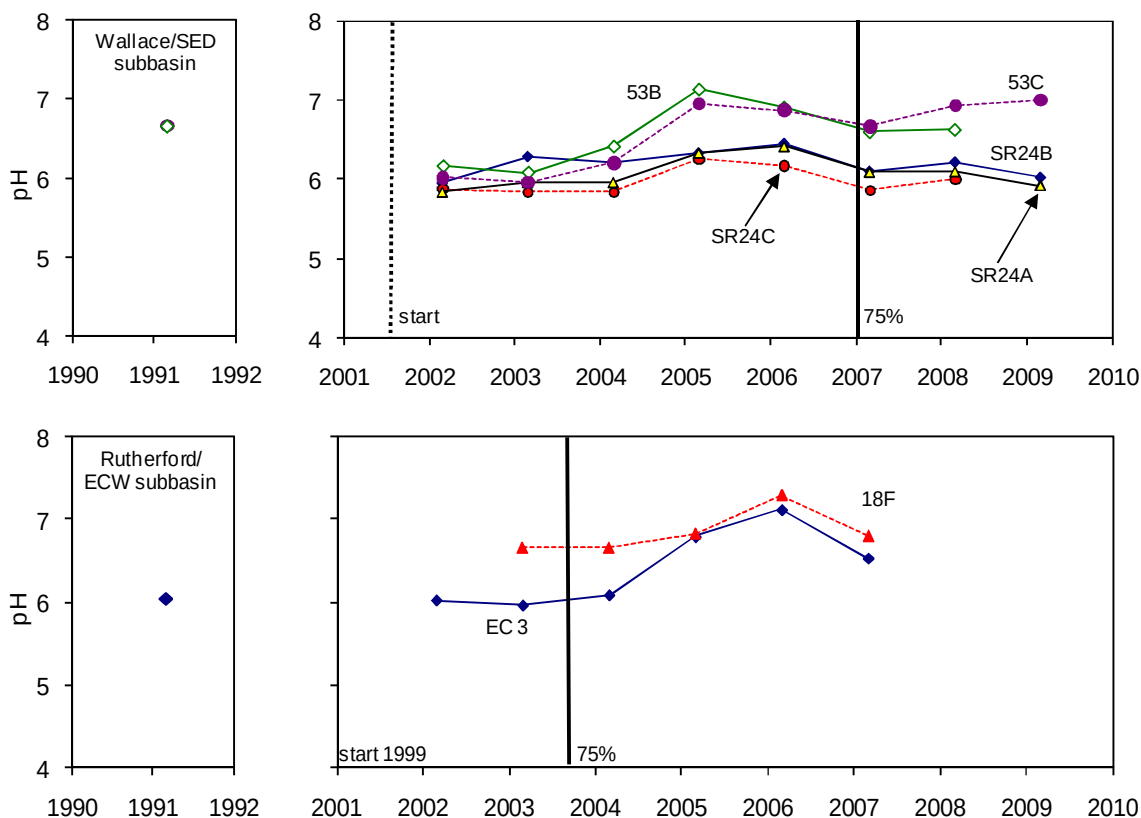


Figure 26. (Cont'd) Average pH.

Table 14. 2008-2010 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	1/30/2008	6.0
18B, Evans Creek Central	2/25/2008	5.7
18B, Evans Creek Central	4/21/2008	5.8

Alkalinity and Hardness

Total alkalinity, generally related directly to carbonate, bicarbonate, and hydroxide content, is a measure of the acid-neutralizing capacity of a water sample. Hardness measures the concentration of the multivalent cations, generally calcium and magnesium, present in a water sample. Increases in alkalinity or hardness, particularly in naturally acidic wetlands, may signal water source or chemistry changes that can alter the stability point of buffering equilibrium, 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 was limited to 1990, 1991, 1992, and 2006-2010 for hardness and 2006-2010 for total alkalinity. Hardness at all water quality sites fell within the low end of the 0-60 mg CaCO₃/L 'soft' classification (Durfor and Becker 1964). Between 1990-1992 and 2006-2010 hardness increased at sites 53A, ADCW1, EC3, 53B, 53C, BBC-26u/s, and SR24A, whereas it decreased at sites BBC-52, BBC-45d/s, BBC-45u/s, BBC-44u/s, 02D, EC-61, and

18B. It remained the same or was variable between years at wetlands BBC-52, BBC-44center, EC-61, EC-4, SR-24B, and SR-24C and Rutherford Creek (18F) (Figure 27). Increases and decreases were generally small in magnitude: less than 6 mg CaCO₃/L, which was within the intra-annual variability range that varies from 1 to 14 mg CaCO₃/L depending on the sampling site. However, hardness levels at EC-3 more than doubled between 1991 and 2006-2007: levels went from approximately 15 to 30 mg CaCO₃/L, an increase that coincided with the increasing conductivity trends observed at this site (Figure 24).

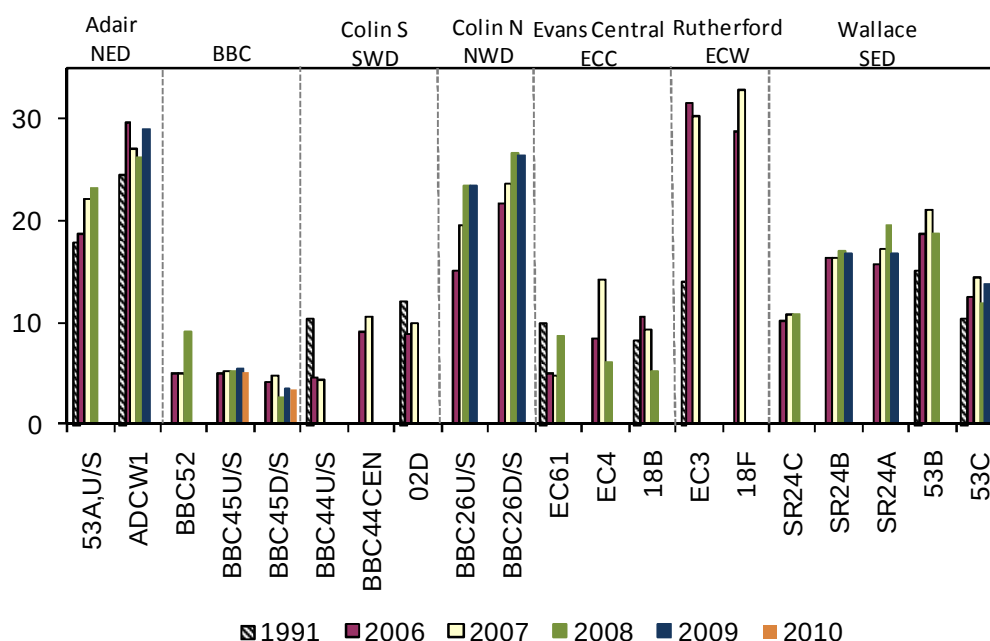


Figure 27. Hardness measurements for UPD water quality sites (1991, 2006-2010).

Values represent averages of from one to five measurements between January and April each year. The dashed vertical lines separate the subbasins. See Figure 23 for locations. Data were only collected in a subset of locations in 1991 and 2008-2010.

Mean winter total alkalinity was highest at wetland EC-3 and its outlet Rutherford Creek (18F) within the ECW subbasin, with mean values ranging from 34 to 43 mg CaCO₃/L. Total alkalinity was less than 30 mg CaCO₃/L at all other sample sites. Each subbasin appeared to have close relationships in alkalinity between the wetlands and their outlet streams. However, each station showed some variability between years (Figure 28), and this variability likely represented natural year-to-year variability, as there is a close relationship between total alkalinity concentrations and streamflow.

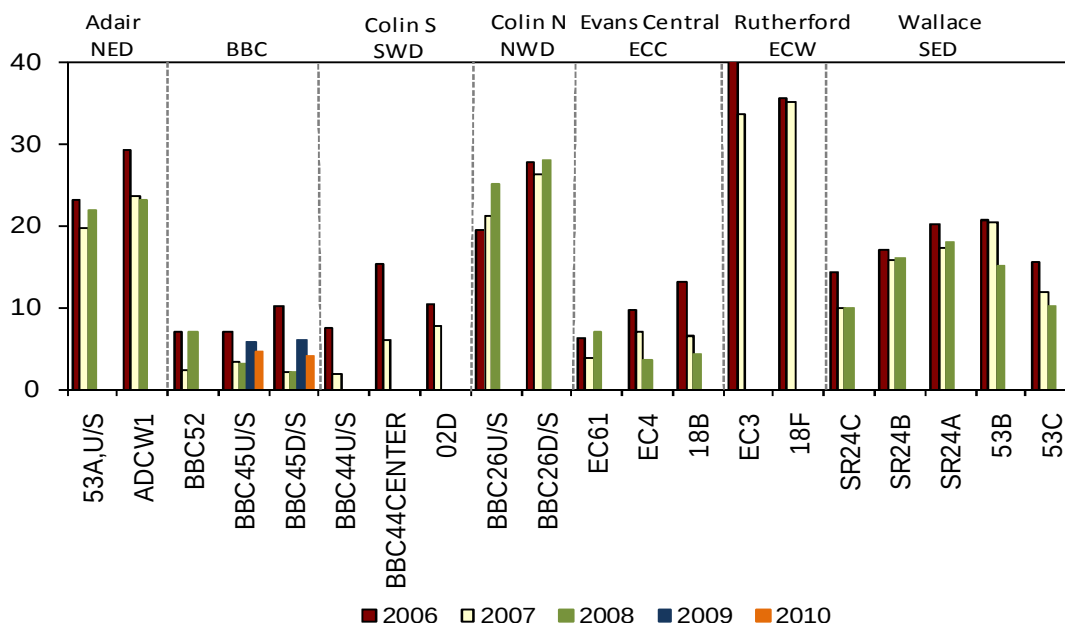


Figure 28. Alkalinity measurements for UPD water quality sites (2006-2007).

Values represent averages of from one to five measurements between January and April each year. The dashed vertical lines separate the subbasins. See Figure 13 for locations. Data were only collected in a subset of locations in 2008-2010.

Other Parameters

Monitoring of dissolved oxygen, turbidity, and metals was not required by the Trilogy and Redmond Ridge monitoring plans for January through April sampling (King County 1999, 2001). Data that were collected on these parameters will be used to inform future sampling, as appropriate, and are reported in Appendices H, I, and J.

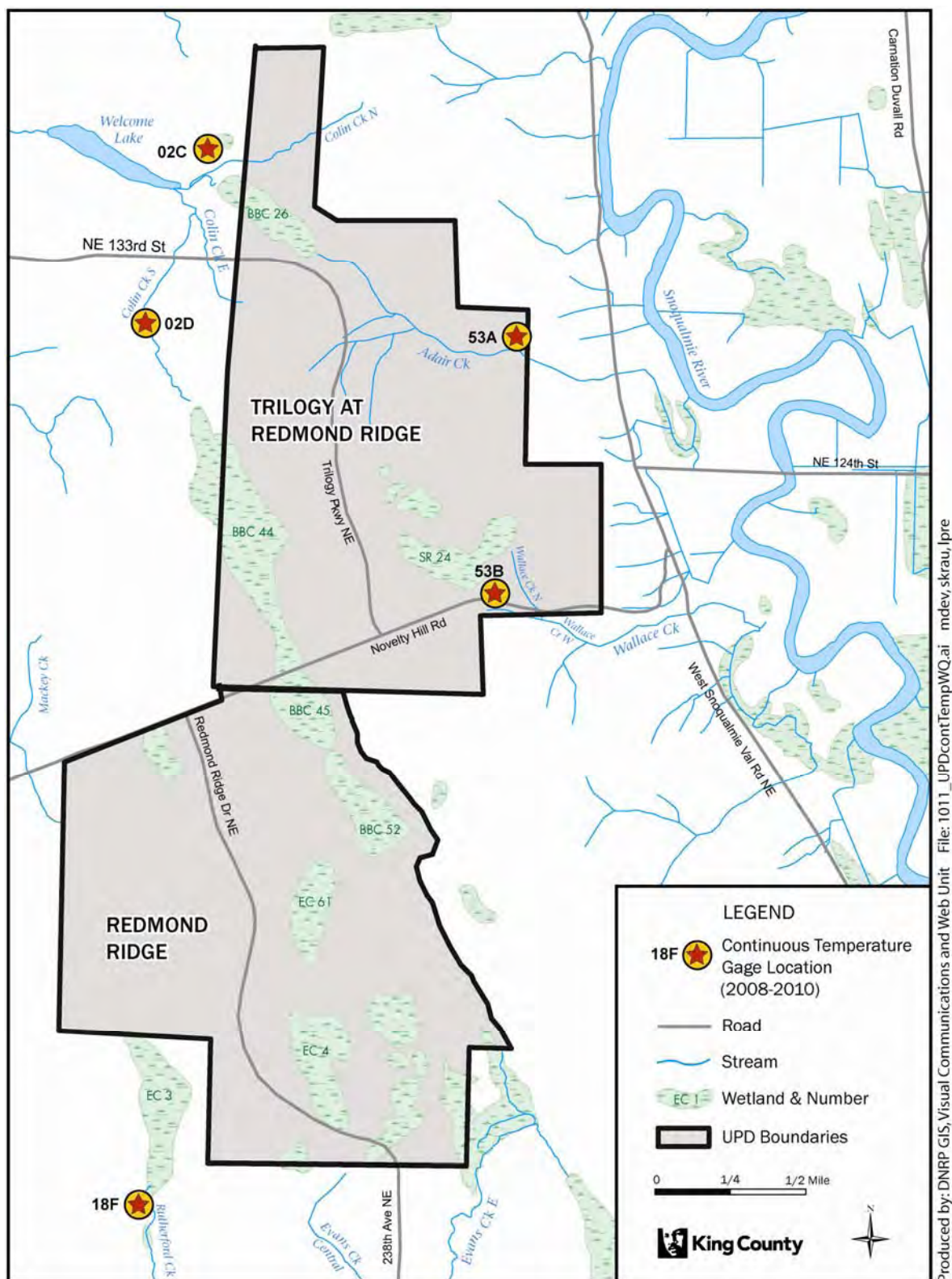
Continuous Sampling

Temperature was the only parameter sampled between 2008 and 2010 in the continuous sampling portion of the monitoring program. Continuous turbidity sampling was ceased in 2005, and all results were presented in the 2007 UPD monitoring report (King County 2010).

Temperature

Continuous temperature sampling took place in Adair, Colin North, Colin South, Rutherford, and Wallace West Creeks (Figure 29). Results generally followed the same annual pattern regardless of location with cooler winter temperatures of less than 5°C and warmer summer temperatures exceeding 15°C. 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 15 summarizes violations of these temperature criteria between 2008 and 2010. Temperatures at Wallace Creek West only violated these criteria in 2009. In contrast, temperatures at Rutherford Creek violated these criteria every year that gage data were available. In 2008, violations were observed at Adair, Colin South and Rutherford Creeks. In 2009, violations were observed at all creeks with active recording devices including Adair, Colin South, Rutherford, and Wallace West Creeks. In 2010, only Rutherford had violations. Large open water wetlands are at the headwaters of Colin South, Colin North,

and Rutherford Creeks less than 500 m (1640 ft) upstream of the water quality monitoring location, and wetland complexes are at the headwaters of Adair and Wallace West. These wetlands naturally contribute to increased summer maximum temperatures as a result of increased residence time of water and the large surface areas exposed to solar radiation prior to its release downstream.



Produced by: DNRP GIS, Visual Communications and Web Unit File: 1011_UPDcontTempWQ.ai mdev, skrau, lpre

Figure 29. Location of five continuous temperature gage locations.
The Colin Creek North (02C) record ended on April 2, 2008. The remaining records all extended into 2010.

Table 15. Stream temperature exceedances of state criteria 2008-2010.

Annual maximum temperatures measured as 7-day average daily temperature (7-DADMax) and dates that violated the state criteria of 17.5°C.

Year	7-DADMax 17.5°C Exceedance Dates	Annual Max 7-DADMax Temperature (°C)
Adair (53A)		
2008	July 3-5; Aug 16-24	18.3
2009	July 28-Aug 6	19.2
2010	none; record ends May 17, 2010	
Colin North (02C)		
2008	none, record ends April 2, 2008	
Colin South (02D)		
2008	July 3-6; August 15-24	19.1
2009	July 21-Aug 9; Aug 21-25	21.6
2010	none	
Rutherford (18F)		
2008	May 19-24; May 30; June 21-July 26; Aug 7-27; Aug 29	21.0
2009	May 21-June 21; June 28-Aug 9; Aug 19-26; Sept 2	23.5
2010	June 11-15; record ends June 15, 2010	17.8
Wallace West (53B)		
2008	none	
2009	July 19-Aug 7; Aug 22-24	21.5
2010	none	

Summer/Fall Wetland Sampling

Water quality data collected during routine and storm events at BBC-45 d/s and BBC-52 in 2009 and 2010 were comparable to conductivity, turbidity, total nitrogen, nitrate-nitrite nitrogen, and total phosphorus collected prior to UPD development in 1991 to 1992 (Table 16). Average pH values from storm sampling at both BBC-45 d/s and BBC-52 and from routine sampling at BBC-45 d/s have dropped approximately half a pH unit between 1991-92 and 2009-10. However, as previously mentioned, obtaining accurate and precise pH measurements in the low conductivity waters of these wetlands was challenging. No predevelopment herbicide data were available; however, all 2009 and 2010 water samples were below detection limits for herbicides. See Appendix K for water quality results for historical and 2009-2010 data by site and sampling date.

Table 16. Water quality data for BBC-45 and BBC-52 wetlands.

Rtn = routine; Strm = storm; N = sample size; MDL = method detection limit.

Wet-land	Type	Years	N	pH		Conductivity (µS/cm)		Turbidity (NTU)		Total N (mg/L)		Nitrate+nitrite-N (mg/L)		Total P (mg/L)	
				Avg	Range	Avg	Range	Avg	Range	Avg	Range	Avg	Range	Avg	Range
BBC-45 (d/s)	Rtn	91-92	12	5.5	5.3-5.8	28.2	17.0-74.0	5.4	0.6-14.0	1.4	0.1-4.4	0.07	0.01-0.44	0.12	0.01-0.28
		09-10	2	4.9	4.8-5.0	20.8	17.4-24.1	3.9	3.9-3.9	1.7	1.1-2.2	<MDL	<MDL	0.12	0.07-0.17
	Strm	91-92	3	6.0	5.1-6.9	20.3	17.0-25.0	2.1	1.1-3.0	1.1	0.6-1.7	0.03	0.01-0.05	0.10	0.03-0.18
		09-10	2	5.1	4.9-5.2	22.2	15.6-28.8	5.2	3.5-6.9	1.2	0.7-1.6	<MDL	<MDL	0.08	0.04-0.11
BBC-52	-	84	3	4.9	4.5-5.3	33.0	21.0-58.0	0.8	0.5-1.0	28.3	20-35	0.69	0.00-1.8	0.02	0.00-0.03
	Rtn	91-92	8	5.6	5.0-6.0	31.0	19.0-55.0	3.6	0.7-16.3	0.6	0.3-1.9	0.16	0.01-0.82	0.04	0.01-0.08
		09-10	2	5.5	5.2-5.7	28.7	19.2-38.2	1.9	1.9-1.9	1.0	0.8-1.0	<MDL	<MDL	0.04	0.03-0.04
	Strm	91-92	3	6.1	5.5-6.8	25.3	22.0-31.0	1.5	0.9-2.0	0.6	0.4-0.7	0.03	0.01-0.04	0.03	0.01-0.03
		09-10	2	5.4	5.0-5.6	22.3	19.1-25.5	2.4	2.0-2.7	0.8	0.7-0.8	0.19	<MDL-0.19	0.04	0.02-0.04

Threshold Exceedance Criteria and Evaluation

The exceedance criteria for water quality were different depending on the sampling regime.

January through April Sampling

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

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

Specific conductivity appeared to be increasing at several sampling locations, and this increase could signify 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 2006-2010 relative to 1991, especially at wetland EC-3.

Continuous Sampling

Continuous stream water quality threshold exceedance criteria were violated if:

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

Seven-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

(2001-2005 and 2007). All five sampling locations were within 500 m (0.3 miles) of open water wetlands where higher summer temperatures would be expected.

Continuous turbidity measurements were discontinued because of equipment fouling problems, but individual measurements were consistently less than 10 NTU. Stream pH measurements during 2008-2010 were less than the state standards of 6.5 at only one stream (Evans Creek Central). However, low pH measurements were expected because the streams drain from headwater wetlands that are naturally very acidic.

Summer/Fall Wetland Sampling

Summer/fall wetland water quality threshold exceedance criteria were violated if there were negative deviations from baseline parameters significant to wetland function, especially trends that correlated with significant changes in amphibian or plant communities (King County 1999). No negative deviations from baseline parameters were observed.

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. Exceedances of state standards for temperature and pH were 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 may be linked to increasing development. However, UPD facility water quality performance monitoring implemented in 2008 indicated that water quality improved within the stormwater facilities and pollutant concentrations leaving the facilities were extremely low or below detection limits (King County 2011a). There are no state water quality standards for conductivity and hardness, and no corrective actions are recommended.

3.8 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), or 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 (Shapiro and Associates Inc. 1984, Herrera Environmental Consultants Inc. 1992, Beak Consultants Incorporated 1995). The dam was later rebuilt in 1986. 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).

Predevelopment, the lake was considered on the threshold of eutrophic conditions based on the Trophic State Index (TSI) classification (Carlson 1977). Its trophic state 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 the inclusion of lake monitoring requirements 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, 2010).

Modifications

From 1996 to 2008, monitoring was conducted by volunteers through the King County Lake Stewardship Program within the Department of Natural Resources and Parks. As a result of budget cuts, Welcome Lake was dropped from this program after 2008. In 2009, water quality sampling was continued by the same volunteer, but sampling was reduced from biweekly between May through October to monthly between June and September. The reduced schedule met the requirements outlined in the Trilogy monitoring plan (King County 2001).

Sampling Recommendations

UPD-related Welcome Lake monitoring was concluded in 2009 and this monitoring met all requirements established in the Trilogy monitoring plan (King County 2001). Future sampling is beyond the scope of the UPD monitoring project, but could be undertaken by alternative, non-UPD sources to assess whether trophic state increases observed from 2003 to 2009 continue, stabilize, or decrease.

Procedures

Water quality data were 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.

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

Water samples were 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), with the exception of 2009 when monthly samples were taken between June and September (4 samples). Water was saved in containers for analysis of total phosphorus, total nitrogen, and chlorophyll-a.

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

The mean TSI was calculated for May-October of each year, except for 2009 when only June-September was available, and the TSI was examined for trends over time⁶⁰. 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

⁶⁰ The TSI can be calculated from any of several parameters including Secchi disk transparency, chlorophyll-a, and total phosphorus (Carlson 1977). For this report the TSI was also calculated from the average of the individual Secchi, chlorophyll-a, and total phosphorus TSI scores.

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. 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, and total phosphorus TSI scores, Welcome Lake had a TSI score in the eutrophic range (>50) in 1996 and in the mesotrophic range (40-50) every year from 1997 to 2009 (Figure 30). Over the period of measurement, the TSI score declined slowly to a minimum in 2003 in the middle of the mesotrophic range (43.1), but it began rising slowly after that through 2009, when it reached the upper range of mesotrophy. The correlation coefficient for the earlier declining trend was stronger (0.7284) than for the subsequent increasing trend suggested by the later data (0.5899), but if this indicated increase continues, the lake might once again be in the eutrophic range. One factor that may have contributed to the apparent rise is that in 2009 an algae bloom in July produced an abnormally high chlorophyll-a value that may have moved the seasonal average toward a higher value than if data had been collected bimonthly for May–October.

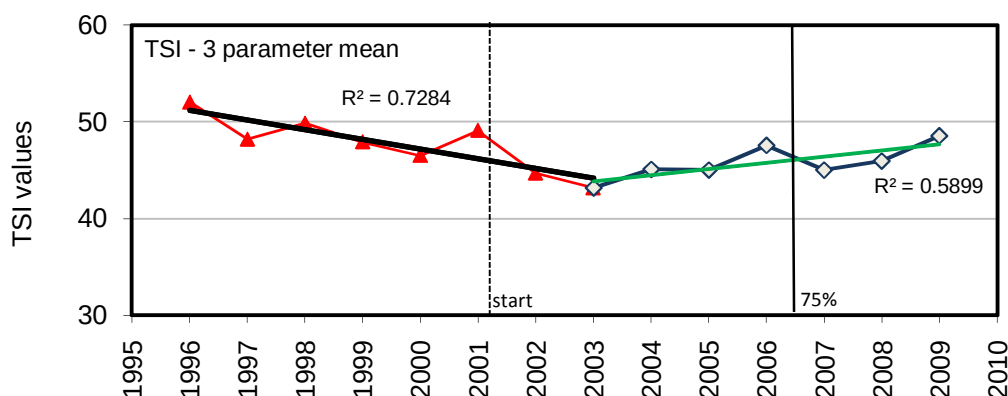


Figure 30. Welcome Lake average TSI scores (1996-2007).

Welcome Lake was sampled bimonthly between May and October 1996 to 2008 and monthly between June and September 2009 near the middle of the lake at 3.3 ft (1-m) depth. TSI was averaged from Secchi depth, chlorophyll-a, and total phosphorus TSI scores. The dashed vertical line represents the start of construction (April 2001), and the solid vertical line represents 75 percent buildout (June 2006) within the Welcome Lake subbasin.

TSI values based on chlorophyll-a values were in the eutrophic range in 1996, 1998, 1999, and 2001, and then rose again above eutrophic levels in 2009, based largely on one high value measured in July of that year (Figure 31). The chlorophyll-a concentrations had the highest year-to-year variability. This variability has been noted at other lakes around King County and is likely influenced by the complex 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). The TSI score based on total phosphorus was in the eutrophic range in 1996 and 1997 only, but has risen steadily from a low of 41.6 in 2003 to a level in the upper mesotrophic range in 2009. The TSI score based on Secchi depth varied from mid to high mesotrophic throughout the study period with no

discernable trend. This score was probably highly affected by the humic acids draining from upstream wetlands. The dissolved organic molecules of the humic acids cause the yellow-tea color of the water and are an important factor in water clarity.

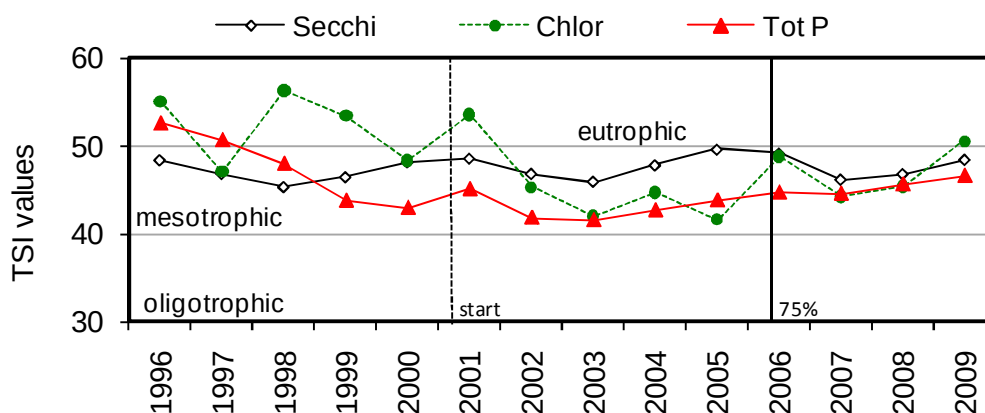


Figure 31. Welcome Lake individual parameter TSI scores (1996-2009).

TSI scores were calculated for each parameter: Secchi depth, chlorophyll-a (Chlor), and total phosphorus (Tot P). Data were averaged from bimonthly samples between May and October 1996 to 2008 and monthly samples between June and September 2009. 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 percent buildout (June 2006) within the Welcome Lake subbasin.

See Appendix L for additional Welcome Lake results (e.g., phosphorus, chlorophyll-a, nitrogen, Secchi, and temperature).

Threshold Exceedance Criteria and Evaluation

Welcome Lake threshold exceedance criteria were violated if there was 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 average TSI score 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. In the two following years, the average TSI was 45.9 in 2008 and 48.5 in 2009. Both 2007 and 2008 TSI values were lower than the predevelopment range of 46.5 (2000) to 52.0 (1996). While the 2009 value was above the lower end of the predevelopment range, it was still lower than the upper threshold and does not exceed the criterion set in the DMP.

Corrective Actions

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

3.9 Groundwater Hydrology

Shallow groundwater levels could be influenced by construction and operation of the UPDs because of infiltration and utility line trenches, golf course irrigation, and nearby impervious surfaces (Blackhawk Port Blakely Communities 1992). Groundwater levels also vary according to annual and seasonal variations in precipitation. The objective of the groundwater hydrology

activities was to monitor groundwater levels to assess that UPD construction and development did not impact groundwater resources.

Redmond Ridge

Redmond Ridge groundwater hydrology monitoring was conducted at 12 observation wells (abbreviated OBW in the well nomenclature) within two geologic units: 11 within the Vashon advance aquifer⁶¹ (OBW-1R, -2R, -3R, -4R, -5, -6, -7R, -8, -10, -11, -12) and 1 in pre-Vashon age deposits⁶² (OBW-9) (Figure 32). This monitoring has been conducted by Associated Earth Sciences, Inc. (AESI) on behalf of Quadrant Corporation since October 1995, and results have been presented in biennial reports (The most recently report was released on 1/21/11: Associated Earth Sciences Inc. 2011).

Trilogy

Trilogy groundwater hydrology monitoring was conducted by GeoEngineers (May 1991–October 1992), AESI (April 2004–October 2006), and King County WLRD (December 2009–January 2011) at up to 17 shallow monitoring wells⁶³ (abbreviated MW in the well nomenclature) in shallow perched groundwater within Vashon lodgement till⁶⁴.

⁶¹ The underlying geology and its associated permeability and porosity influence the location and timing of groundwater recharge (Scanlon et al. 2002). The geologic conditions occurring at the UPDs are a direct reflection of glacial activity. The Vashon advance aquifer, composed of sand and gravel, is the primary aquifer at the UPDs. 'Vashon' refers to a period of ice expansion within the Fraser Glaciations; it reached its peak about 15,000 years ago.

⁶² The pre-Vashon age deposits are older glacial and non glacial geologic deposits.

⁶³ 17 wells were monitored in 1991-1992 and 16 wells were monitored in 2004-2006 and 2009-2010. MW-3 was monitored in 1991-1992, but not in subsequent years because repeated attempts to locate it by both AESI and King County staff were unsuccessful.

⁶⁴ Vashon lodgement till is glacially transported and deposited and is a poorly sorted unit.

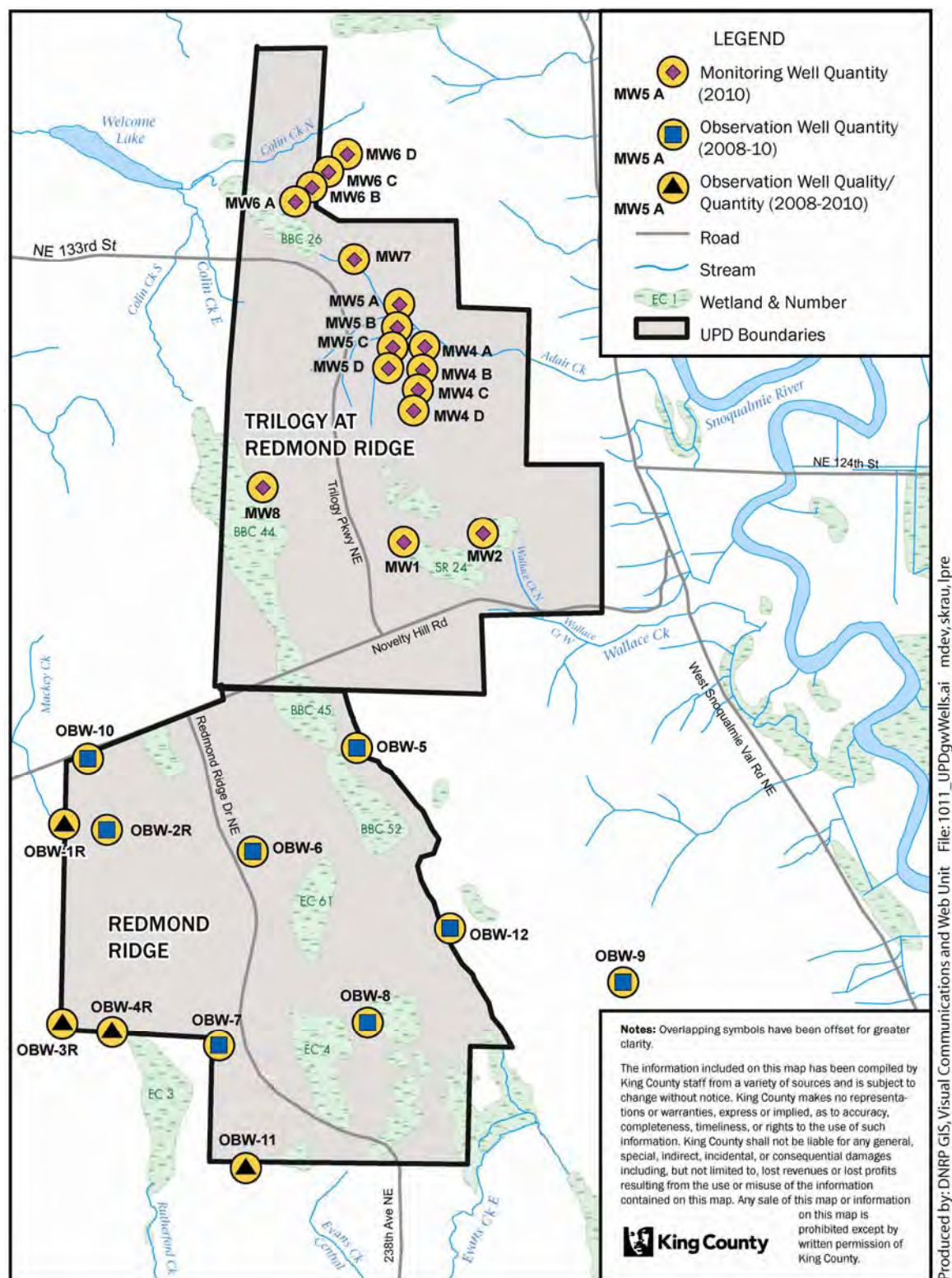


Figure 32. Groundwater well monitoring locations.

Redmond Ridge had 12 observation wells (OBW) monitored for water level by AESI in 2008, 2009, and 2010, including four monitored for water quality by WLRD in 2010. Trilogy had 16 monitoring wells (MW) monitored for water level in 2010.

Modifications

No modifications to the groundwater hydrology monitoring activities have occurred.

Sampling Recommendations

Water level monitoring at the observation wells required by the Redmond Ridge monitoring plan (King County 1999) will be conducted twice more in 2011 (likely in May and October) to achieve 8 years post-75 percent Redmond Ridge buildout, which was reached in fall 2003. Monthly hydrology monitoring within the Trilogy UPD and groundwater quality monitoring within the Redmond Ridge UPD was discontinued after January 2011.

Procedures

Redmond Ridge

The 12 Redmond Ridge wells that were monitored between 2008 and 2010 were installed between 1996 and 1998 except OBW-7R, which was installed in summer 2001 to replace OBW-7. Continuous hourly groundwater level measurements were logged at these 12 observation wells. In addition, groundwater level elevations were manually recorded once per month with an electric tape (Associated Earth Sciences Inc. 2011).

Trilogy

The 16 Trilogy wells that were monitored in the 2010 water year were installed in 1991. All 16 wells were located within the 200-ft vegetated buffer of nearby wetlands. Of the 16 wells, 12 were oriented in groups of four wells each in a line, or transect, extending roughly perpendicular to wetland fringes. Wells within the same transect were denoted by the same well number (e.g., MW-4) followed by the letters A, B, C, or D (see Figure 32 for the locations of the wells). Groundwater level elevations were manually recorded at the 16 wells once per month with an electric tape using the same procedures as the Redmond Ridge locations.

Results

Redmond Ridge

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. 2011). These letters consistently report that groundwater levels at Redmond Ridge fluctuate between 0.6 and 3.0 m (2 and 10 ft) in response to precipitation, with a lag time between peak precipitation and peak groundwater levels of 2 to 7 months. Well water levels increased during 2007-2010 compared to the low levels from 2001-2006 when average annual rainfall was lower than the long term average. 2010 peak water levels in wells OBW-5, -6, and -8 were the highest recorded during the fifteen year monitoring period. Additional details of the Redmond Ridge groundwater hydrology results can be found in the January 21, 2011 AESI report (Associated Earth Sciences Inc. 2011).

Trilogy

The 2010 water year groundwater level data showed similar patterns compared to the 2004-2006 data. The Trilogy groundwater levels appeared to respond to precipitation similar to groundwater levels at Redmond Ridge wells by increasing during wet periods and decreasing during dry periods (Figure 33 shows MW-4B, see Appendix M for all wells).

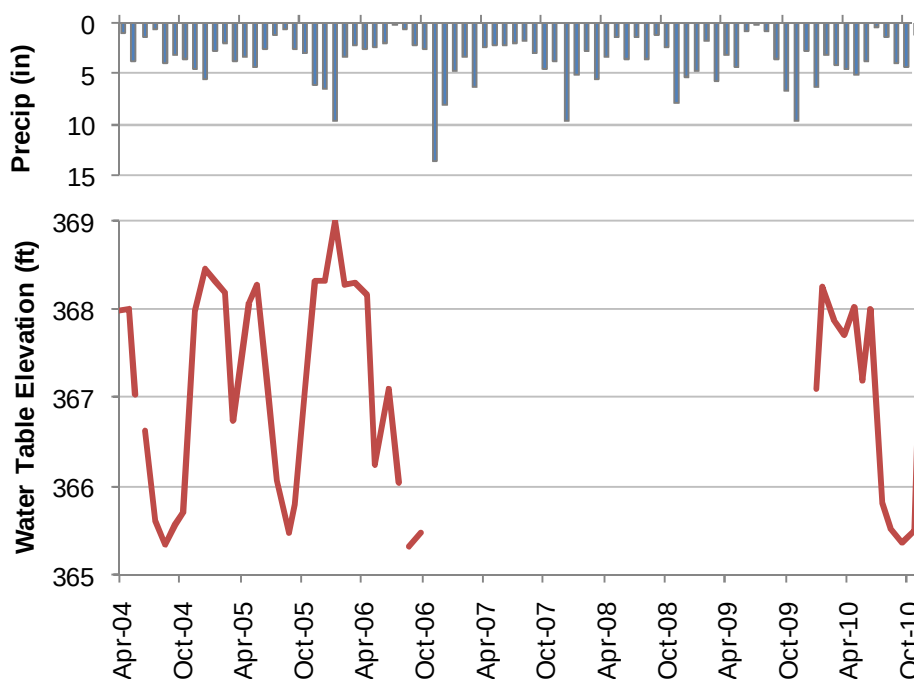


Figure 33. Precipitation and groundwater level data for MW-4B (2004-2006 and 2010).

This figure is one example of 'typical' groundwater level results with monthly water level responding to precipitation. The top figure displays the total monthly precipitation and the bottom figure displays the groundwater level measured once monthly. See Appendix M for data from all Trilogy wells.

Post development groundwater level data were compared across four years: 2010, 2005, 2006, and 1992 at most groundwater well locations. Figure 34 shows an example of groundwater fluctuations that were representative for most well locations (see Appendix M for data from all wells). Exceptions to these patterns were observed at wells MW-6A, MW-6B, MW-7, and MW-1. Groundwater levels at MW-6A, MW-6B, and MW-7 appeared to have increased approximately 2 feet in 2005, 2006, and 2010 relative to 1992 levels (Figure 35). MW-6A and -6B were adjacent to BBC-26 where higher wetland water levels have been observed because of increased beaver activity⁶⁵. No UPD monitoring was conducted near MW-7 and no direct observations were available. However, beaver activity or the construction of 232nd Ave NE could impact wetland water levels and subsequently groundwater levels at MW-7.

⁶⁵ The increased depth of BBC26 has been noted during amphibian breeding surveys and a float tube was necessary to complete surveys. In addition, the staff plate on the BBC 26 crest stage gage has been entirely submerged for several years.

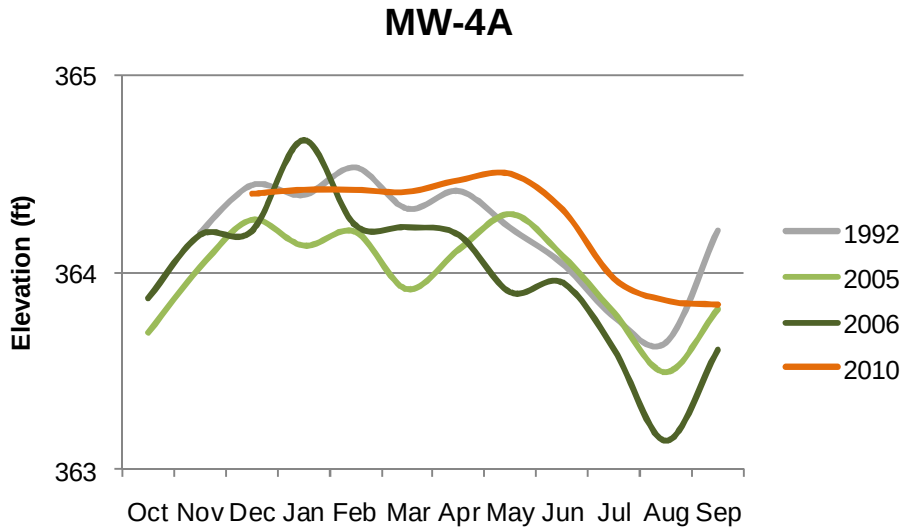


Figure 34. Groundwater level data for MW-4A (1992, 2005, 2006, 2010). 1992 was predevelopment, 2005 and 2006 was during construction, and 2010 was after 75% subbasin buildout. This figure displays just one example of 'typical' groundwater level results with annual groundwater elevation falling within a similar range regardless of year. See Appendix N for data from all Trilogy wells.

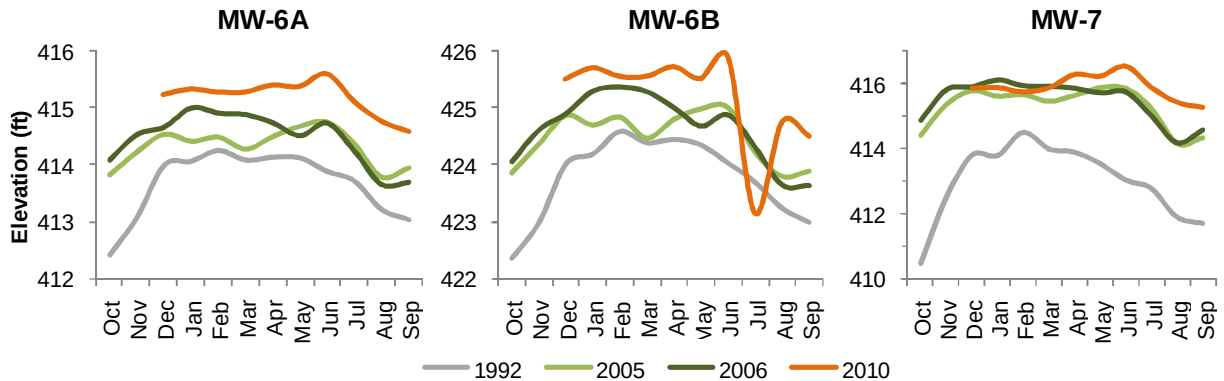


Figure 35. Groundwater level data for MW-6A, -6B, and -7 (1992, 2005, 2006, 2010). 1992 was predevelopment, 2005 and 2006 was during construction, and 2010 was after 75% subbasin buildout. 2005, 2006, and 2010 water levels were elevated relative to 1992 at all three wells. See Appendix N for data from all Trilogy wells.

The groundwater level changes observed at MW-1 were unique relative to all other groundwater data (Figure 36 and Appendix N). Summer through fall (~ June through December) groundwater levels at MW-1 appeared to have increased in 2005, 2006, and 2010 relative to 1992 levels resulting in less intra-annual variation (Figure 36). Because of the scarcity of data collected between 1992 and 2005, the reason for this observation is unknown.

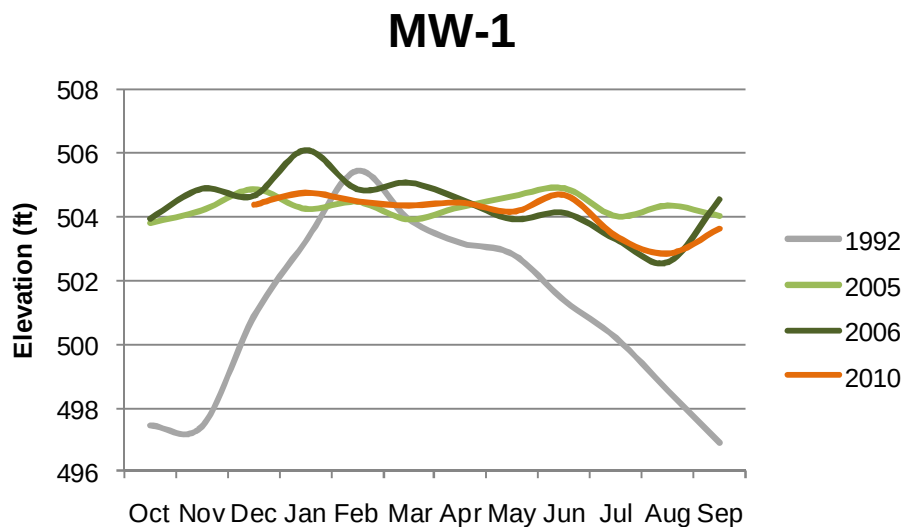


Figure 36. Groundwater level data for MW-1 (1992, 2005, 2006, 2010). 1992 was predevelopment, 2005 and 2006 was during construction, and 2010 was after 75% subbasin buildout. The changes shown at MW-1 in groundwater levels from 1992 to 2005, 2006, and 2010 are unique relative to other groundwater data (See Appendix N for all Trilogy well data).

Threshold Exceedance Criteria and Evaluation

The exceedance criteria for groundwater hydrology were different for Redmond Ridge and Trilogy.

Redmond Ridge

Redmond Ridge groundwater hydrology threshold exceedance criteria were violated if the seasonally adjusted average level of wells met either of the following criteria and deviations were not explainable by precipitation or off-site well pumping (King County 1999):

- wells OBW-1 through -8 water levels declined more than 3 ft (0.91 m) below baseline levels for more than two consecutive years or
- wells OBW-5 through -8 water levels declined more than 11 ft (3.35 m) below baseline levels for more than two consecutive years.

These threshold criteria have not been exceeded.

Trilogy

Trilogy groundwater hydrology threshold exceedance criteria were not established in the Trilogy monitoring plan (King County 2001)⁶⁶. Qualitative assessments were conducted to determine whether post-development groundwater levels deviated beyond the range of variation established during baseline groundwater level monitoring. 2010 groundwater levels followed precipitation patterns and generally matched the range of annual fluctuations observed in 2005 and 2006.

⁶⁶ Methods were proposed Trilogy Monitoring Plan (King County 2001) for using a regression analysis to determine a band of 'allowable variation' from predevelopment data to which post-development groundwater levels could be compared. This analysis was not conducted because it was deemed time intensive and probably of little value due to the limited post-development record (only data collected during the 2010 water year were after 75% buildout).

Levels at four wells (MW-1, -6A, -6B, and -7) were beyond the range of 1992 groundwater levels. However, in all four cases groundwater levels were elevated, rather than depleted, relative to predevelopment conditions. Concerns about UPD groundwater impacts prior to development all were related to water source depletion. Corrective actions for the Shallow Well Protection Program established for neighboring wells were all triggered only if groundwater levels lowered, not if they rose.

Corrective Actions

No corrective actions are recommended at Redmond Ridge or Trilogy for this component of the monitoring plan.

3.10 Groundwater Quality

Groundwater quality monitoring was required in the Redmond Ridge monitoring plan (King County 1999) to verify that there was no degradation from infiltration facilities to groundwater approaching sensitive receiving bodies (i.e., streams and wetlands) or wells. The UPD groundwater quality monitoring focused on nitrate-nitrite nitrogen. Nitrate-nitrite contamination of groundwater can be caused by human activity (e.g., runoff from fertilizer use, leaching from septic tanks, sewage) and therefore it is a commonly used indicator of groundwater quality⁶⁷. No groundwater quality monitoring was required in the Trilogy monitoring plan (King County 2001).

Modifications

Quarterly groundwater quality monitoring was required for fecal coliform bacteria and nitrate-nitrite nitrogen at six wells in Redmond Ridge (King County 1999) (Figure 32). However, sampling was conducted less frequently than quarterly and two wells (OBW-10⁶⁸ and OBW-5⁶⁹) were omitted because of constraints related to the well design.

Sampling Recommendations

It is recommended that groundwater quality monitoring be concluded because there has been sufficient lag time from the start of UPD construction to detect impacts.

Procedures

Groundwater samples were collected using a Grundfos pump. Field measurements including conductivity, dissolved oxygen, pH, turbidity, temperature, and oxidation reduction potential were recorded at regular purge volumes using a QED MP20 Flow Cell meter. Once these

⁶⁷ NO₂+NO₃ can also derive from erosion of natural deposits (U.S. Environmental Protection Agency 2009).

⁶⁸ WLRD staff attempted to sample OBW-10 in January and September 2010 and in both instances the fine particles within the well clogged the pump causing sampling delays and added equipment maintenance expenses. OBW-10 was constructed as a nested well consisting of a 6" steel casing with a nested 2" PVC casing. This design is no longer allowed in Washington State and contributed to the fine particle contamination. Some type of well purging and/or modification would have to occur to enable sampling. It is neither prudent nor cost-effective to sample this well at this time.

⁶⁹ 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 level monitoring that has been taking place since November 1995.

parameters stabilized⁷⁰, water samples were collected in pre-labeled containers for nitrate-nitrite nitrogen and fecal coliform bacteria. Samples were kept on ice and delivered to KCEL where each parameter was analyzed using standard operating procedures following strict protocols for sample handling and quality assurance.

Results

Redmond Ridge groundwater quality results from September 21, 2010, at well OBW-11 and October 13, 2010, at wells OBW-1R, -3R, and -4R are presented in Table 17. Fecal bacteria levels were below the method detection limit (MDL) at all wells. Nitrate-nitrite nitrogen ranged from 0.267 to 2.07 mg/L, which was within the range of values observed during predevelopment monitoring at regional wells (0.11-5.50 mg/L; see Appendix O for regional data) and at the lower end of the range of values observed for the Redmond-Bear Creek valley between 2001 and 2004 (0.02-6.65 mg/L) (King County 2005a).

Table 17. 2010 groundwater quality results.

Samples were collected on 9/21/10 (well OBW-1R) or 10/13/10 (well OBW-3R, -4R, and -11). MDL is the method detection limit.

WQ Parameter	1R	3R	4R	11
Nitrate-nitrite Nitrogen (mg/L)	0.267	0.0748	2.07	0.0554
Fecal Coliform (CFU/100mL)	<MDL	<MDL	<MDL	<MDL
Conductivity(μmhos/cm)	277	92	159	123
Dissolved Oxygen (mg/L)	9.1	2	7.5	
Oxidation Reduction Potential (mV)	165	146	109	-146
pH	6.37	6.11	6.77	7.24
Sample Depth (m)	14.6	16.5	18.3	18.3
Sample Temperature (deg C)	11.3	8.7	11	10.8
Turbidity (NTU)	1.7	1.1	1.2	9.3

The Federal EPA and Washington State drinking water standards (U.S. Environmental Protection Agency 2009, Washington State Board of Health 2009) require a Maximum Contaminant Level (MCL) for nitrate nitrogen of less than 10 mg/L. The data collected for UPD groundwater quality was nitrate-nitrite nitrogen, however nitrate-nitrite concentrations can be taken as approximately comparable to nitrate concentrations because the concentration of nitrite is typically negligible compared to the concentrations of nitrate (King County 2005a). Nitrate-nitrite nitrogen concentrations measured at UPD wells in 2010 were well below this MCL.

Threshold Exceedance Criteria and Evaluation

A repeated trend in water quality degradation away from baseline water quality would violate the thresholds established in the Redmond Ridge monitoring plan (King County 1999) and could trigger appropriate corrective actions. However, no baseline monitoring took place in the observation wells where groundwater quality monitoring was required. Fecal coliform bacteria and nitrate-nitrite nitrogen levels fell within the range of data observed from other public and private wells completed within the Vashon Advance Aquifer (Appendix O).

⁷⁰ At least three well volumes were typically purged at wells OBW-1, -3, and -4; less than three well volumes were usually purged at OBW-11, which is a 6" diameter steel well instead of a 2" PVC well like the others.

Corrective Actions

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

4.0 UPD MONITORING PROGRAM CONCLUSION

WLRD is bringing the Redmond Ridge and Trilogy Urban Planned Development (UPD) post development natural resource monitoring program to completion⁷¹ and all WLRD monitoring and analysis concludes with the publication of this document. This includes stream, wetland, groundwater, and facility monitoring components. Rationales for this decision are summarized in Table 18 and are described in more detail for each relevant monitoring component in the following sections.

Table 18. Summary of UPD monitoring components: status, future proposals, and rationales.

Component	Brief Status Summary	Proposal and Brief Rationale
Facilities	Facility water quality monitoring requirements have been met; facility hydrology requirements were met at a subset of sites.	Discontinue all facility monitoring, shifting focus to analysis of existing data. A subset of facilities has been monitored and results can be extrapolated from this subset. King County ownership and inspections ensure ponds are managed to standards. UPD facility designs are generally not proposed for future use. Natural resource monitoring does not indicate major problems.
Streams	Sediment and water quality monitoring requirements have been met. Benthic macroinvertebrates, fish, stream cross sections, and hydrology were very close and except for cross sections were on track to be completed at the end of the 2011 water year.	Sampled all sites for hydrology, bugs, fish, and cross sections in 2010 and brought to conclusion.
Wetlands	Hydrology, amphibian breeding surveys, and water quality monitoring requirements have been met at all wetlands except BBC 45 and BBC 52. The BBC basin within RR has not reached 75% buildout. Monitoring end dates are set relative to the 75% buildout date.	Discontinue hydrology, amphibian breeding, vegetation, and WQ monitoring at BBC 45 & 52. Within RR no parcels remain to be developed that will drain to BBC52. Concurrent development of RRE will complicate detection of RR impacts. Monitoring at other wetlands has been concluded and no impacts have been definitively linked to UPD development.
Groundwater	GW quantity has been conducted by AESI since 1996 for RR; 2006 & 2010 water year collection has been completed by AESI & WLRD for Trilogy. GW quality (RR only) was collected in summer 2006 and fall 2010.	Discontinue all GW monitoring by October 2011. Duration requirements have been met relative to 75% buildout. Water levels follow precipitation patterns and there is no evidence of water source depletion. There is no indication of the presence of fecal coliforms and nitrate-nitrite nitrogen concentrations fall within the range of regional predevelopment conditions. The time lag from construction start has been sufficient to detect impacts.
Reporting	2006 midpoint and 2007 wateryear reports summarized monitoring through 2007 wateryear; 2008-2010 report issued April 2011.	2008-2010 report: the final monitoring report issued by King County WLRD issued April 2011. One additional Redmond Ridge Groundwater report to be issued by December 2011 by AESI on behalf of Quadrant.

⁷¹ Both the Trilogy and Redmond Ridge monitoring plans (King County 1999, 2001) state that changes to the monitoring plans may be made in consultation with others but are ultimately under the purview of WLRD. The recommendations laid out here have been discussed with and agreed upon by representatives of both King County DDES and Quadrant Homes and the publication of this report confirms approval by WLRD management.

4.1 UPD Stream Monitoring–Duration Modification

Stream monitoring included benthic macroinvertebrate, fish, stream cross section, water quality, sediment and hydrology monitoring. Rationale for concluding stream monitoring follows.

1. Sediment and water quality monitoring requirements have been met.
2. Benthic macroinvertebrates, fish, and hydrology monitoring requirements have been met for Rutherford, Evans Central, Evans East, Wallace, and Colin South Creeks and these components were on track to be completed by the end of the 2011 water year at Adair and Colin North Creeks. Where property access permission was obtained, all sites were visited in 2010 to complete a final analysis of each monitoring component. Completing this sampling in 2010, rather than 2011, meant that:
 - a. For benthic macroinvertebrate and fish monitoring, Adair Creek and Colin Creek North were sampled at 1/3/4 years after 75% buildout instead of 1/3/5 years. However, both streams were still sampled three times and according to the Trilogy monitoring plan (King County 2001) streams could either be sampled for 3 years following 75% buildout or at intervals of 1/3/5 years.
 - b. For hydrology monitoring, Adair Creek and Colin Creek North have 4 years post 75% buildout data instead of 5 years.
3. The modified monitoring requirements for stream cross sections recommended in the 2007 report (King County 2010) have been met⁷².
4. The Adair Creek monitoring reach was greatly modified by channel scouring caused by the flush of water from a breached beaver dam on April 28, 2010. Continued monitoring of Adair Creek following this event will not help determine whether the UPD development has influenced stream biology, channel shape, or hydrology.

4.2 UPD Wetland Monitoring: BBC-45 and BBC-52

Wetland monitoring duration requirements have been met at all UPD wetlands except BBC-45 and BBC-52. WLRD recommends concluding hydrology⁷³, amphibian breeding, vegetation, and

⁷² Recommendations in the 2007 monitoring report (King County 2010) suggested limiting monitoring to Wallace and Adair Creeks except for a final site visit at least 7 years after construction start up. The majority of stream cross section monitoring locations except Wallace and Adair Creeks were immediately downstream of large headwater wetlands in very low gradient systems where changes in channel shape were not likely. Final 2010 measurements were at 7 (Colin N), 8 (Adair), and 9 years (Wallace and Colin S) after construction start as opposed to the 10 years originally proposed prior to the 2007 modified recommendations.

water quality monitoring at the BBC-45 and BBC-52 wetlands within the Redmond Ridge UPD beginning in October 2010⁷⁴ and rationale for this decision follows.

1. The BBC basin within Redmond Ridge has not reached 75% buildout (Lowe 2005, 2008, 2010), which dictates the monitoring duration, and no date is currently projected.
2. Within the Redmond Ridge UPD, no parcels remaining to be developed will drain to BBC-52.
3. The BBC-52 and BBC-45 monitoring requirements were established to detect impacts from the Redmond Ridge UPD development. However, development of Redmond Ridge East along the eastern margins of both wetlands will make it challenging to attribute impacts only to Redmond Ridge. Similarly, BBC-45 will also be influenced by future projects on Novelty Hill Road and the power line access road.
4. BBC-45 was impacted by Novelty Hill Road and the power line access road before any UPD development commenced. Baseline water quality and amphibian data reflect these impacts and complicate interpretation of UPD monitoring data.
5. Hydrology, amphibian breeding, and water quality monitoring at other UPD wetlands has been concluded and no impacts were conclusively linked to UPD development at these other monitoring locations.

4.3 UPD Groundwater Monitoring

Groundwater quality sampling was only required at Redmond Ridge for fecal coliforms and nitrate-nitrite nitrogen (King County 1999). Groundwater quantity monitoring was required at both Trilogy and Redmond Ridge (King County 1999, 2001) and field collection has been conducted by both WLRD and Associated Earth Sciences, Inc. (AESI) on behalf of Quadrant. Rationale for concluding these components of the UPD monitoring program follows.

Groundwater Quality

The final groundwater quality samples were collected in October 2010. This termination date was deemed appropriate for the following reasons.

⁷³ The Redmond Ridge East Developer and their consultants rely on water level data from BBC-52 as part of the Redmond Ridge East monitoring program. The interruption of data collection needs to be communicated to them followed by a discussion of how they can continue to meet their data needs and requirements.

⁷⁴ October 2010 is the beginning of the 2011 wateryear.

1. No predevelopment data were collected in the wells where monitoring was required. Therefore, predevelopment conditions had to be estimated from regional well data.
2. Over 7 years elapsed since 75% Redmond Ridge buildout was triggered in October 2003. Monitoring was only required for three years beyond 75% UPD buildout (King County 1999).
3. Groundwater quality from 2006 and 2010 do not indicate any presence of fecal coliforms or elevated levels of nitrate-nitrite nitrogen when compared to regional predevelopment conditions. (See section 3.10 in this report for groundwater quality results).
4. Nitrate generally moves with water and based on Redmond Ridge groundwater level data it has been estimated that precipitation takes approximately 2-6 months to reach the water table (Associated Earth Sciences Inc. 2011). Therefore, any UPD impacts related to nitrate-nitrite nitrogen concentrations in the groundwater would have been detected in 2006 and 2010 if present given that UPD construction began in 1999 and 75% Redmond Ridge UPD buildout was reached in November 2003.
5. There have been no known complaints of groundwater quality violations from adjacent well owners or water districts.

Trilogy Groundwater Quantity

The final Trilogy groundwater quantity samples were collected in January 2011. This termination date was deemed appropriate based on the data summaries and justifications that follow.

1. Data collection for monthly water level monitoring at 16 Trilogy wells (MW-1, -2, -4a, -4b, -4c, -4d, -5a, -5b, -5c, -5d, -6a, -6b, -6c, -6d, -7, -8⁷⁵) included:
 - a. May 1991-October 1993 (GeoEngineers)
 - b. April 2004-September 2006 (AESI)
 - c. December 2009-January 2011 (WLRD)
2. 2010 water levels followed precipitation patterns and were generally comparable to previous data collected with the exception of four wells: MW-1, -6A, -6B and -7 (see section 3.9 in this report for groundwater hydrology results). Observed water levels at MW-6A, -6B and -7 were higher year round in the 2005, 2006, and 2010 water years compared to 1992 levels, likely due to beaver activity that increased water levels at adjacent wetlands. Observed winter water levels at MW-1 in 2005, 2006, and 2010 were higher than 1992 winter water levels.
3. Predevelopment concerns regarding impacts to groundwater involved water source depletion and corrective actions for the Shallow Well Protection Program established for neighboring wells were all triggered only if groundwater levels lowered. In all cases, post development results do not suggest groundwater source depletion.

⁷⁵ Repeated efforts have failed to locate monitoring well #3; therefore no monitoring has taken place at this location since 1993.

4. Sampling duration requirements have been met. Groundwater hydrology monitoring was required by the Trilogy monitoring plan for 3 years following 75% subbasin buildout (King County 2001). January 2011 was at least three years following 75% subbasin buildout (NED subbasin including wells MW-4A to D, MW-5A to D, and MW-7) to almost 4.5 years (SWD subbasin, including well MW-8).
5. Trilogy groundwater level results appear to correspond to precipitation similar to the groundwater levels at Redmond Ridge, where groundwater levels have been monitored continuously since the 1996 water year. The limited data set from the Trilogy groundwater level sites makes it difficult to draw strong conclusions about UPD development.
6. Surface hydrology data at onsite wetlands and streams draining the Trilogy UPD do not indicate any patterns of drying or any significant shifts in timing and delivery of water. See the 2008-2010 hydrology report for more information (King County 2011c).

Redmond Ridge Groundwater Quantity

The final Redmond Ridge groundwater quantity sampling will be completed by AESI in October 2011 with two additional sample visits (likely in May and October) and one final report to be completed by December 2011. This termination date was deemed appropriate based on the data summaries and justifications that follow.

1. Continuous water level monitoring with monthly site visits has been conducted starting between 1995 and 1998 by AESI at 12 observation wells (OBW-1 through 12) or their replacement equivalents (e.g., OBW-1R). Water levels from OBW-5, -6, -7R, and -8 through -12 are unaffected by recharge facilities and record background water levels.
2. The Redmond Ridge monitoring plan (King County 1999) calls for observing groundwater levels for 8 years following 75% UPD buildout. 75% buildout of the Redmond Ridge UPD was reached in November, 2003 and therefore sampling will be concluded in October, 2011.
3. Redmond Ridge groundwater level results correspond to precipitation with a lag of approximately 2 to 7 months (Associated Earth Sciences Inc. 2011).
4. Surface hydrology data at onsite wetlands and streams draining the Redmond Ridge UPD do not indicate any patterns of drying or any significant shifts in timing and delivery of water. See the 2008–2010 hydrology report for more information (King County 2011c).

4.4 UPD Facilities Monitoring

Facilities monitoring included both hydrology and water quality components. The original purpose of the facilities monitoring program was to provide data for pond performance and Hydrological Simulation Program Fortran (HSPF) model verification and to evaluate water

quality effectiveness of representative facilities (King County 1999, 2001). Rationale for concluding the facilities monitoring follows.

1. Water quality⁷⁶ facility monitoring was completed in 2008. A subset of water level⁷⁷ facility monitoring has been completed and results can be extrapolated from these facilities. Facilities and downstream wetland and stream data analyzed through the 2010 water year indicate there aren't any major problems linked to UPD development.
2. King County inspections and ownership of residential facilities ensure facilities are managed to standards.
 - a. Privately maintained commercial facilities remain under private ownership and do not transfer to King County. Up to a 50% discount of Surface Water Management (SWM) fees applies if facilities are maintained correctly; therefore there is incentive for proper maintenance and upkeep. King County inspects regularly and follows up with a letter to the owner detailing maintenance recommendations.
 - b. Residential facilities are scrutinized when the maintenance defect bond is set to expire. Once under King County's ownership they have regular inspections to check structures, determine whether sedimentation cells require cleaning, and to verify aquatic benches are meeting their planting schedule.
3. The water quality facility designs used at both UPDs are unique and are not reflected in the 2005 or 2009 King County Surface Water Design Manuals (SWDM) (King County 2005b, 2009). These designs have not been replicated widely⁷⁸, are being replaced in two UPD locations⁷⁹, and WLRD does not expect this design or wet pond sizing methodology to be used again in King County.
4. No major downstream hydrological or biological problems have been observed based on stream and wetland monitoring. See the 2006 UPD midpoint report (King County 2006),

⁷⁶ Water quality verification was done in 2008 at two Redmond Ridge facilities (ECW1B-1 & ECW3-1) and three Trilogy facilities (NED9, NWD4, and SWD3).

⁷⁷ Crest-stage monitoring was conducted at 5 Redmond Ridge facilities from 2003-2009 (BC2-1, ECW3-3, MC1-1, MC2-1, MC4-1); continuous water level monitoring was conducted at three Redmond Ridge facilities (ECW1B-1, ECW3-1, and ECW2-1) and one Trilogy facility (NWD1-A). In addition two bypass systems were monitored at Trilogy (Adair Creek and Wallace Creek bypasses).

⁷⁸ The wet pond with aquatic bench design used at Redmond Ridge and in some locations at Trilogy may also have been used at Grand Ridge/Issaquah Highlands. However, this design has not been repeated extensively as it is not considered effective and it is no longer a standard design per current adopted standards (Personal communications with King County Stormwater Services staff including Curt Crawford, Steve Foley, Andrew McDonald, and Dave Hancock).

⁷⁹ Within Trilogy, NED6 and SED2 are being converted by the developer from the original aquatic bench design to wetpond designs from the 1998 surface water design manual (King County 1998) with the unique criteria of $V_b/V_r = 3.5$ (V_b = Volume of the basin; V_r = Volume of runoff generated by the design storm).

the 2007 UPD monitoring report (King County 2010), or various sections of this 2008-2010 report for results and analysis.

5. No major facility overflows have been reported throughout the years by landowners, homeowners associations, or King County staff working in the area.
6. Hydrology models such as HSPF are great to use as design tools and for performing sensitivity analyses. However, they do not predict actual conditions⁸⁰ accurately enough to be used as a benchmark for performance monitoring as was originally proposed in the Trilogy and Redmond Ridge monitoring plans. Therefore, alternative metrics were selected for analyzing stream, wetland, and facility hydrology in the 2008-2010 reports (King County 2011c, b).

⁸⁰ WLRD used the Trilogy HSPF model to compare predevelopment model predictions to actual conditions, but the model consistently underestimated peak flows.

5.0 REFERENCES

- Army Corps of Engineers. 2007. Special Public Notice: Final Regional Conditions and Water Quality Certification and Coastal Zone Management Consistency Decisions for the 2007 Nationwide Permits in Washington State. Seattle District Regulatory Branch, US Army Corps of Engineers, Seattle, Washington.
- Associated Earth Sciences Inc. 2011. Ground Water Level Monitoring Redmond Ridge King County, Washington. January 21, 2011 letter from AESI to Lisa Lee at King County. Prepared by Jennifer H. Saltonstall and Curtis J. Koger, Associated Earth Sciences Inc., Kirkland, Washington.
- Azous, A. L. 1991. An analysis of urbanization effects on wetland biological communities. University of Washington, Seattle, Washington.
- Azous, A. L. and R. R. Horner, editors. 2001. Wetlands and urbanization: implications for the future. 1st edition. Lewis Publishers, Washington, D.C.
- B.C. Ministry of Environment. 1997. Fish collection methods and standards: version 4.0. B.C. Ministry of Environment, Lands and Parks, Fish Inventory Unit, Vancouver, British Columbia.
- Beak Consultants Incorporated. 1995. Northridge UPD technical report on water quality. Kirkland, Washington.
- Blackhawk Port Blakely Communities. 1992. Monitoring Plan for Blakely Ridge Active Senior MPD., Issaquah, Washington.
- Booth, D. and C. R. Jackson. 1997. Urbanization of aquatic systems -- degradation thresholds, stormwater detention, and the limits of mitigation. *Journal of the American Water Resources Association* **22**:1077-1090.
- Booth, D. B. 1990. Stream-channel incision following drainage-basin urbanization. *Water Resources Bulletin* **26**:407-417.
- Brown, L. R., R. H. Gray, R. M. Hughes, and M. Meador, editors. 2005. Effects of urbanization on stream ecosystems. American Fisheries Society, Bethesda, Maryland.
- Carlson, R. E. 1977. A trophic state index for lakes. *Limnology and Oceanography* **22**:361-368.
- Clinton, B. D. and J. M. Vose. 2006. Variation in stream water quality in an urban headwater stream in the Southern Appalachians. *Water, Air, and Soil Pollution* **169**:351-353.
- Comes, R. D., V. F. Bruns, and A. D. Kelley. 1978. Longevity of certain weed and crop seeds in fresh water. *Weed Science* **26**:336-344.

- Comings, K., H. Wachter, and D. Booth. 2001a. 2000 facilities and stream monitoring report for the Redmond Ridge and Trilogy at Redmond Ridge Urban Planned Developments. Center for Urban Water Resources Management, Department of Civil & Environmental Engineering, University of Washington, Seattle.
- Comings, K., H. Wachter, and D. Booth. 2001b. 2001 facilities and stream monitoring report for Redmond Ridge and Trilogy at Redmond Ridge Urban Planned Developments. Center for Urban Water Resources Management, Department of Civil & Environmental Engineering, University of Washington, Seattle.
- Comings, K., H. Wachter, T. Garrido, and D. Booth. 2000. 1998-1999 facilities and resources monitoring report for the Blakely and Redmond Ridge Urban Planned Developments. Center for Urban Water Resources Management, Department of Civil & Environmental Engineering, University of Washington, Seattle.
- Cooke, S. S., editor. 1997. A Field Guide to the Common Wetland Plants of Western Washington & Northwestern Oregon. Seattle Audubon Society, Seattle, WA.
- Cowx, I. G. and P. Lamarque, editors. 1990. Fishing with electricity, applications in freshwater fisheries management. Blackwell Scientific Publications, Oxford.
- Durfor, C. N. and E. Becker. 1964. Public water supplies of the 100 largest cities of the United States, 1962. 1812, U.S. Geological Survey.
- Elzinga, C. L., Daniel W. Salzer, and John W. Willoughby. 1998. Measuring and Monitoring Plant Populations. Page 492 in BLM, editor. Government Printing Office.
- Findlay, C. S. T. and B. Josée. 2000. Response Time of Wetland Biodiversity to Road Construction on Adjacent Lands. *Conservation Biology* **14**:86-94.
- Gibbs, J. P., K. K. Whiteleather, and F. W. Schueler. 2005. Changes in frog and toad populations over 30 years in New York State. *Ecological Applications* **15**:1148-1157.
- Greig-Smith, P., editor. 1983. Quantitative plant ecology. University of California Press, Berkley, California.
- Hach. 1999. Portable Turbidimeter Model 2100P instrument and procedure manual. Report Number: dd/rb 6-3-98 7ED, Hach Company, Loveland, Colorado.
- Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. Forest Service General Technical Report RM-245. U.S. Department of Agriculture.
- Hatton, T. J., N. E. West, and P. S. Johnson. 1986. Relationships of the error associated with ocular estimation and actual total cover. *Journal of Range Management* **39**:91-92.
- Heaney, J. P. and W. C. Huber. 1984. Nationwide assessment of urban runoff impact on receiving water quality. *Water Resources Bulletin* **20**:35-42.

- Herrera Environmental Consultants Inc. 1992. Surface water quality evaluation: proposed Northridge development. Prepared for Quadrant Corporation, Bellevue, Washington.
- Herrera Environmental Consultants Inc. 1995. Surface Water Quality Evaluation, Proposed Blakely Ridge Master Plan Development. Originally prepared for Blackhawk/Port Blakely Communities. Published as Appendix C in Northwest Engineering Company's Drainage Master Plan, Blakely Ridge UPD prepared for Blakely Ridge Limited Partnership, March 1995.
- Hitchcock, C. L. and A. Cronquist. 1973. *Flora of the Pacific Northwest*. University of Washington Press., Seattle, Washington.
- Hope-Simpson, J. F. 1940. On the errors in the ordinary use of subjective frequency estimations. *Journal of Ecology* **28**:193-209.
- Horner, R. R. 2001. Introduction, chapter 1. Pages 3-28 in A. L. Azous and R. R. Horner, editors. *Wetlands and urbanization: implications for the future*. Lewis Publisher, New York.
- Horner, R. R., S. S. Cooke, L. E. Reinelt, K. A. Ludwa, and N. T. Chin. 2001a. Water quality and soils, chapter 2. Pages 47-67 in A. L. Azous and R. R. Horner, editors. *Wetlands and urbanization: implications for the future*. Lewis Publisher, New York.
- Horner, R. R., S. S. Cooke, L. E. Reinelt, K. A. Ludwa, N. T. Chin, and M. Valentine. 2001b. Effects of watershed development on water quality and soils, chapter 9. Pages 237-254 in A. L. Azous and R. R. Horner, editors. *Wetlands and urbanization: implications for the future*. Lewis Publishers, Washington, D.C.
- Horner, R. R., J. J. Skupien, E. H. Livingston, and H. E. Shaver. 1994. *Fundamentals of urban runoff management: technical and institutional issues*. Terrene Institute, Washington, DC.
- Hugh G. Goldsmith and Associates, I. 1996. Northridge UPD/FCC Urban Planned Development Master Drainage Plan (MDP). Prepared for Quadrant Corporations, Bellevue, Washington.
- Hugh G. Goldsmith and Associates, I. 2006. Redmond Ridge & Trilogy Midpoint Review: Summary of Document of Findings. Prepared for The Quadrant Corporation by Hugh G. Goldsmith & Associates, Inc.
- Hugh G. Goldsmith and Associates Inc. 2007. Redmond Ridge East post development monitoring program. Prepared for Redmond Ridge East, LLC in April 2007 and revised November 2007, Bellevue, Washington.
- Jones, L. L. C., W. P. Leonard, and D. H. Olson. 2005. *Amphibians of The Pacific Northwest*. Seattle Audubon Society, Seattle, WA.
- Karr, J. R. and E. W. Chu. 1999. *Restoring life in running waters: better biological monitoring*. Island Press, Washington, DC.

- Karr, J. R., K.D.Fausch, P.L.Angermeier, P.R. Yant, and I. J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5:1-28.
- Kennedy, K. A. and P. A. Addison. 1987. Some considerations for the use of visual estimates of plant cover in biomonitoring. *Journal of Ecology* **75**:151-157.
- King County. 1993. Draft Environmental Impact Statement: Blakely Ridge Urban Planned Development. Department of Development and Environmental Services, SEPA Section, Bellevue, Washington.
- King County. 1998. 1998 King County Surface Water Design Manual. Department of Natural Resources and Department of Development and Environmental Services Land Use Services Division, Seattle.
- King County. 1999. Redmond Ridge monitoring plan. King County, Department of Natural Resources, Water and Land Resources Division, Seattle, Washington.
- King County. 2001. Post-development monitoring plan for the Trilogy at Redmond Ridge (formerly Blakely Ridge) Urban Planned Development (UPD). King County, Department of Natural Resources, Water and Land Resources Division, Seattle, Washington.
- King County. 2002. 1997 King County Bog Inventory. King County Surface Water Management, Seattle, Washington.
- King County. 2005a. King County groundwater protection program ambient groundwater monitoring: 2001-2004 results. Prepared by Anchor Environmental and King County Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, Washington.
- King County. 2005b. King County surface water design manual. Department of Natural Resources and Parks, Water and Land Resources Division, Seattle, Washington.
- King County. 2006. Trilogy and Redmond Ridge Urban Planned Development (UPD) Natural Resources Monitoring Midpoint Review. Prepared by Jennifer O. Wilhelm, Raymond K. Timm, Sally Abella, Kyle Comanor, David Funke, Kenneth Johnson, and Klaus O. Richter, Water and Land Resources Division, Seattle, Washington.
- King County. 2009. Surface Water Design Manual. King County Department of Natural Resources and Parks, Seattle, WA.
- King County. 2010. Trilogy and Redmond Ridge Urban Planned Development (UPD) Annual Monitoring Report: Water Year 2007. Prepared by Jo Wilhelm, Scott Stolnack, David Funke, and Ray Timm. Water and Land Resources Division, Seattle, Washington.
- King County. 2011a. 2008 Wet Weather Stormwater Facility Water Quality Monitoring at the Trilogy and Redmond Ridge Urban Planned Developments (UPDs). Prepared by Raymond Timm. Water and Land Resources Division, Seattle, Washington.

- King County. 2011b. Trilogy and Redmond Ridge Urban Planned Development (UPD) Final Facilities Monitoring Report. Prepared by David Funke. Water and Land Resources Division, Seattle, Washington.
- King County. 2011c. Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Final Stream and Wetland Hydrologic Monitoring Assessment. Prepared by Curtis DeGasperi. Water and Land Resources Division, Seattle, Washington.
- King County Environmental Lab. 1999. Standard operating procedure for trace metals section: preparation of water and wastewater samples for analysis of total and dissolved metals by inductively coupled plasma optical emission spectrometer (ICP-OES). SOP # 06-02-001-002. King County Environmental Lab, Seattle, Washington.
- King County Environmental Lab. 2003. Standard operating procedure for alkalinity. SOP# 03-03-001-003. King County Environmental Lab, Seattle, Washington.
- King County Environmental Lab. 2006. Standard operating procedure for trace metals section: instrumental analysis for total mercury in environmental samples by cold vapor atomic absorption spectrometry. SOP#06-01-004-004. King County Environmental Lab, Seattle, Washington.
- Klein, R. D. 1979. Urbanization and stream quality impairment. *Water Resources Bulletin* **15**:948-963.
- KPFF Consulting Engineers. 2004. Redmond Ridge phasing plan June 14, 2004. Seattle, Washington.
- Kulzer, L., S. Luchessa, S. Cooke, R. Errington, and F. Weinmann. 2001. Characteristics of the low-elevation *Sphagnum*-dominated peatlands of Western Washington: a community profile. King County Department of Natural Resources, Seattle, Washington.
- Lepš, J. and V. Hadincová. 1992. How reliable are our vegetation analyses? *Journal of Vegetation Science* **3**:119-124.
- Lowe, R. 2005. UPD build out language and request. Electronic mail communication to J. Wilhelm on 12/14/2005., King County, Department of Development and Environmental Services.
- Lowe, R. 2008. UPD build out language and request, 2008 update. Electronic mail communication to J. Wilhelm on 2/21/2008, King County, Department of Development and Environmental Services.
- Lowe, R. 2010. UPD build out language and request, 2010 update. Electronic mail communication and phone conversation with J. Wilhelm on 11/09/2010, King County, Department of Development and Environmental Services.

- Lyons, J., L. Wang, and T. D. Simonson. 1996. Development and validation of an index of biotic integrity for coldwater streams in Wisconsin. *North American Journal of Fisheries Management* **16**:241-255.
- May, C. W., E. B. Welch, R. R. Horner, J. R. Karr, and B. W. Mar. 1997. Quality indices for urbanization effects in Puget Sound Lowland streams. *Water Resources Series Technical Report No. 154*, Washington Department of Ecology, Seattle.
- Merritt, R. W. and K. W. Cummins, editors. 1996. *An Introduction to the Aquatic Insects of North America*. Kendall/Hunt Publishing Company, Dubuque, Iowa.
- Morley, S. A. 2000. Effects of urbanization on the biological integrity of Puget Sound lowland streams: Restoration with a biological focus. University of Washington, Seattle.
- Northwest Engineering Company. 1995. Drainage Master Plan, Blakely Ridge UPD. report number 598-03.00, prepared for Blakely Ridge Limited Partnership, Bellevue, Washington.
- Otak Incorporated. 2006. Trilogy at Redmond Ridge development phasing May 2, 2006. Kirkland, Washington.
- Platts, W. S., W.F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. General Technical Report INT-138, United States Department of Agriculture, Ogden, Utah.
- Pojar, J. and A. MacKinnon, editors. 1994. *Plants of the Pacific Northwest Coast*. Lone Pine Publishing, Redmond, WA.
- Pollard, W. R., G. F. Hartman, C. Groot, and P. Edgell. 1997. Field Identification of Coastal Juvenile Salmonids. Harbour Publishing, Madeira Park, British Columbia, Canada.
- Raedeke Associates Inc. 1995. Master drainage plan - chapter 4: wetland assessment for the Northridge UPD, King County, Washington. Raedeke Associates, Inc., Seattle, Washington.
- Reinelt, L. E. and R. R. Horner. 1990. Characterization of the hydrology and water quality of palustrine wetlands affected by urban stormwater. Puget Sound Wetlands and Stormwater Management Research Program, Seattle, Washington.
- Reinelt, L. E., R. R. Horner, and A. L. Azous. 1998. Impacts of urbanization on palustrine (depressional freshwater) wetlands - research and management in the Puget Sound region *Urban Ecosystems* **2**:219-236.
- Reinelt, L. E. and B. L. Taylor. 2001. Effects of watershed development on hydrology, chapter 8. Pages 221-235 in A. L. Azous and R. R. Horner, editors. *Wetlands and urbanization: implications for the future*. Lewis Publishers, Washington, D.C.

- Richter, B. D., J.V. Baumgartner, D.P. Braun, and J. Powell. 1998. A spatial assessment of hydrologic alteration within a river network. *Regulated Rivers: Research & Management* **14**:329-340.
- Richter, K. O. and A. L. Azous. 2001. Amphibian distribution, abundance and habitat use, chapter 5. Pages 143-166 in A. L. Azous and R. R. Horner, editors. *Wetlands and urbanization: implications for the future*. Lewis Publisher, Washington, DC.
- Richter, K. O. and E. C. Ostergaard. 1999. King County wetland-breeding amphibian monitoring program: 1993-1997 summary report. King County, Department of Natural Resources, Water and Land Resources Division Seattle, Washington.
- Scanlon, B., R. Healy, and P. Cook. 2002. Choosing appropriate techniques for quantifying groundwater recharge. *Hydrogeology Journal* **10**:18-39.
- Shapiro and Associates Inc. 1984. Draft Environmental Impact Statement for the Lake of the Woods Development.
- Sumioka, S. S., and N.P. Dion. 1985. Trophic classification of Washington lakes using reconnaissance data. Washington Department of Ecology prepared in cooperation with the United States Geologic Survey, Olympia, Washington.
- Thoms, C., C. C. Corkran, and D. H. Olson. 1997. Basic amphibian survey for inventory and monitoring in lentic habitats. Pages 35-46 in D. H. Olson, W. P. Leonard, and R. B. Bury, editors. *Sampling amphibians in lentic habitats*. Society for Northwestern Vertebrate Biology, Olympia, Washington.
- U.S. Environmental Protection Agency. 2009. Drinking Water Contaminants. U.S. Environmental Protection Agency, The Office of Ground Water and Drinking Water (OGWDW), Washington, DC.
- United States Geological Survey. 1976. Reconnaissance data on lakes in Washington, Volume 2, King and Snohomish Counties. USGS Water Supply Bulletin 43 **2**.
- WAC Chapter 173-201A. 2003. Water quality standards for surface water of the State of Washington. Chapter 173-201A Washington Administrative Code (WAC), Washington State Legislature, Olympia, Washington.
- Wang, L., J. Lyons, and P. D. Kanehl. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. *Environmental Management* **28**:255-266.
- Washington Department of Ecology. 2006. Water quality standards for surface water of the State of Washington. Chapter 173-201A Washington Administrative Code (WAC), Washington State Legislature, Olympia, Washington.
- Washington State Board of Health. 2009. Group A public water supplies. Chapter 246-290 Washington Administrative Code (WAC), Washington State Board of Health, Olympia, Washington.

- Williams, R. W., R. M. Laramie, and J. J. Ames. 1975. A Catalog of Washington Streams and Salmon Utilization, Volume 1, Puget Sound. Washington Department of Fisheries, Olympia, WA.
- Windmiller, B., R.N. Homan, J.V. Regosin, L.A. Willitts, D.L. Wells, and J. M. Reed. 2008. Breeding amphibian population declines following loss of upland forest habitat around vernal pools in Massachusetts, USA. Pages 41-51 in J. C. Mitchell, R. E. Jung, and B. Bartholomew, editors. Urban Herpetology. Herpetological Conservation, Volume 3, Society for the Study of Amphibians and Reptiles, Salt Lake City, Utah.
- Wisseman, R. W. 1998. NuWiss Master 98 benthic macroinvertebrate database (with an additional clinger database compiled by Leska Fore) on the SalmonWeb website. <<http://www.cbr.washington.edu/salmonweb/taxon/NuWiss.Master98-2.xls>> and <<http://www.cbr.washington.edu/salmonweb/taxon/clingertaxa.xls>>
- Wolcott, E. E. 1964. Lakes of Washington. Volume 1: Western Washington. Water Supply Bulletin **14**.
- YSI Incorporated. 1998. YSI model 85 handheld oxygen, conductivity, salinity, and temperature system operations manual. YSI Incorporated, Yellow Springs, Ohio.
- Zika, P. F. 2003. The native subspecies of *Juncus effusus* (Juncaceae) in western North America. *Brittonia* **55**:150-156.
- Zippin, C. 1956. An evaluation of the removal method of estimating animal populations. *Biometrics* **12**:163-189.
- Zippin, C. 1958. The removal method of population estimation. *Journal of Wildlife Management* **22**:82-90.

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 ⁸¹
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

⁸¹ The Washington Department of Fisheries created a catalog of Washington's streams in the 1970s (Williams et al. 1975). The stream catalog assigns stream numbers as a method of identifying individual streams. The first two digits of the stream number represent the Water Resources Inventory Area (WRIA) followed by four numbers that were assigned consecutively from north to south. Not all streams within a basin were assigned a stream number, and no updates to the catalog have been made.

Appendix B. Precipitation data for water years 2008-2010

Table B-1. Daily and monthly precipitation totals in inches for water year 2008.

Day	2008 Water Year											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.22	0.00	0.02	0.00	0.02	0.05	0.00	0.01	0.00	0.00	0.15	0.01
2	0.36	0.00	1.44	0.39	0.02	0.01	0.00	0.00	0.00	0.02	0.00	0.00
3	0.18	0.00	3.65	0.41	0.00	0.24	0.00	0.01	0.49	0.97	0.00	0.00
4	0.71	0.02	0.26	0.07	0.00	0.01	0.32	0.00	0.09	0.00	0.00	0.00
5	0.01	0.00	0.01	0.15	0.17	0.01	0.08	0.00	0.13	0.00	0.00	0.00
6	0.02	0.00	0.00	0.20	0.28	0.00	0.10	0.00	0.56	0.06	0.00	0.00
7	0.59	0.10	0.00	0.19	0.03	0.04	0.13	0.00	0.34	0.00	0.00	0.00
8	0.00	0.03	0.00	0.35	0.70	0.02	0.08	0.00	0.00	0.00	0.00	0.00
9	0.00	0.22	0.01	0.09	0.43	0.00	0.00	0.01	0.36	0.00	0.31	0.00
10	0.07	0.57	0.03	0.56	0.45	0.41	0.00	0.00	0.35	0.00	0.01	0.00
11	0.00	0.00	0.00	0.03	0.11	0.04	0.00	0.00	0.03	0.00	0.00	0.00
12	0.00	0.44	0.00	0.14	0.17	0.00	0.00	0.00	0.01	0.00	0.00	0.00
13	0.00	0.01	0.27	0.00	0.03	0.41	0.11	0.01	0.00	0.00	0.00	0.00
14	0.01	0.09	0.05	0.53	0.00	0.45	0.52	0.01	0.00	0.00	0.00	0.00
15	0.08	0.85	0.19	0.01	0.09	0.32	0.13	0.01	0.00	0.00	0.00	0.00
16	0.02	0.22	0.20	0.00	0.02	0.43	0.01	0.00	0.00	0.00	0.00	0.00
17	0.25	0.40	0.40	0.12	0.00	0.01	0.06	0.01	0.00	0.00	0.00	0.00
18	0.17	0.00	0.53	0.27	0.01	0.04	0.32	0.00	0.00	0.00	0.13	0.00
19	0.82	0.13	0.46	0.51	0.01	0.04	0.38	0.00	0.00	0.00	0.28	0.02
20	0.23	0.03	0.52	0.05	0.00	0.14	0.15	0.02	0.00	0.00	0.88	0.57
21	0.22	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.02	0.15
22	0.00	0.01	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
23	0.00	0.00	0.52	0.00	0.00	0.76	0.08	0.00	0.00	0.00	0.00	0.00
24	0.60	0.01	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	1.05	0.10
25	0.01	0.00	0.19	0.00	0.00	0.12	0.18	0.01	0.00	0.00	0.16	0.21
26	0.01	0.37	0.10	0.28	0.00	0.32	0.00	0.00	0.00	0.00	0.30	0.02
27	0.00	0.01	0.19	0.01	0.05	0.03	0.01	0.00	0.00	0.01	0.23	0.00
28	0.00	0.12	0.11	0.15	0.05	0.37	0.37	0.00	0.00	0.00	0.00	0.00
29	0.01	0.00	0.12	0.46	0.18	0.38	0.13	0.00	0.00	0.10	0.01	0.00
30	0.00	0.01	0.00	0.07		0.63	0.24	0.00	0.00	0.01	0.00	0.00
31	0.00		0.00	0.09		0.17		0.00		0.14	0.00	
Max. daily total	0.82	0.85	3.65	0.56	0.70	0.76	0.52	0.02	0.56	0.97	1.05	0.57
Monthly total	4.59	3.65	9.67	5.14	2.82	5.45	3.43	0.11	2.36	1.31	3.53	1.25
Hist. monthly total ^a	4.50	7.23	5.96	5.87	3.59	4.39	3.32	3.06	1.97	0.84	1.36	2.30

^a Historical average monthly precipitation totals measured at rain gage 02V from October 1995 through September 2010

Table B-2. Daily and monthly precipitation totals in inches for water year 2009.

Day	2009 Water Year											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.00	0.27	0.15	0.37	0.01	0.25	0.70	0.00	0.00	0.00	0.00	0.00
2	0.04	0.50	0.08	0.07	0.01	0.12	0.89	0.17	0.00	0.00	0.00	0.00
3	0.29	0.22	0.01	0.01	0.00	0.11	0.24	0.01	0.00	0.00	0.00	0.10
4	0.19	1.22	0.00	0.00	0.00	0.01	0.01	0.28	0.00	0.00	0.00	0.02
5	0.02	0.00	0.00	0.69	0.01	0.64	0.00	1.02	0.00	0.00	0.00	0.35
6	0.39	1.34	0.01	0.42	0.10	0.01	0.00	0.59	0.00	0.00	0.00	0.74
7	0.01	0.81	0.42	1.14	0.00	0.12	0.00	0.24	0.00	0.00	0.00	0.35
8	0.02	0.16	0.12	0.65	0.01	0.21	0.00	0.03	0.00	0.00	0.00	0.01
9	0.10	0.32	0.11	0.01	0.26	0.03	0.01	0.00	0.00	0.00	0.00	0.00
10	0.00	0.04	0.00	0.72	0.19	0.09	0.04	0.00	0.00	0.00	0.23	0.00
11	0.00	0.51	0.00	0.22	0.08	0.15	0.07	0.09	0.00	0.00	0.42	0.00
12	0.00	1.03	0.71	0.08	0.00	0.00	0.78	0.12	0.00	0.05	0.02	0.00
13	0.41	0.15	0.37	0.00	0.00	0.00	0.09	0.40	0.00	0.04	0.04	0.00
14	0.03	0.00	0.00	0.00	0.00	0.55	0.05	0.11	0.00	0.00	0.06	0.00
15	0.01	0.00	0.00	0.00	0.05	0.29	0.00	0.00	0.00	0.00	0.00	0.00
16	0.01	0.00	0.00	0.01	0.01	0.17	0.00	0.00	0.00	0.00	0.00	0.05
17	0.00	0.00	0.14	0.00	0.00	0.07	0.24	0.00	0.00	0.00	0.00	0.00
18	0.01	0.02	0.01	0.01	0.00	0.01	0.00	0.41	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.01	0.14	0.01	0.92	0.27	0.00	0.00	0.82
20	0.01	0.40	0.00	0.01	0.00	0.27	0.00	0.00	0.02	0.00	0.00	0.01
21	0.24	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00
22	0.00	0.05	0.01	0.01	0.09	0.22	0.02	0.00	0.05	0.00	0.00	0.00
23	0.09	0.01	0.00	0.00	0.31	0.12	0.03	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.24	0.68	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.25	0.01	0.00	0.30	0.65	0.00	0.00	0.02	0.01	0.03	0.00
26	0.00	0.01	0.00	0.00	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.02	2.23	0.15	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.13	0.58	0.01	0.00	0.43	0.04	0.00	0.00	0.00	0.00	0.02
29	0.00	0.18	0.20	0.02		0.18	0.01	0.00	0.00	0.00	0.00	1.02
30	0.00	0.05	0.02	0.04		0.02	0.00	0.00	0.00	0.00	0.00	0.00
31	0.41		0.19	0.00		0.13		0.00		0.00	0.00	
Max. daily total	0.41	1.34	2.23	1.14	0.31	0.68	0.89	1.02	0.44	0.05	0.42	1.02
Monthly total	2.28	7.80	5.37	4.64	1.84	5.71	3.23	4.39	0.80	0.10	0.80	3.49
Hist. monthly total ^a	4.50	7.23	5.96	5.87	3.59	4.39	3.32	3.06	1.97	0.84	1.36	2.30

^a Historical average monthly precipitation totals measured at rain gage 02V from October 1995 through September 2010

Table B-3. Daily and monthly precipitation totals in inches for water year 2010.

Day	2010 Water Year											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.06	0.01	0.01	0.39	0.02	0.00	0.05	0.04	0.06	0.01	0.00	0.05
2	0.20	0.00	0.00	0.00	0.10	0.16	0.47	0.07	0.35	0.07	0.00	0.00
3	0.00	0.00	0.01	0.04	0.11	0.02	0.11	0.59	0.01	0.02	0.00	0.00
4	0.00	0.00	0.00	0.79	0.02	0.02	0.13	0.13	0.62	0.00	0.00	0.03
5	0.00	0.63	0.01	0.16	0.25	0.01	0.34	0.44	0.04	0.03	0.00	0.03
6	0.00	1.38	0.00	0.00	0.06	0.00	0.00	0.00	0.32	0.00	0.00	0.42
7	0.00	0.61	0.00	0.00	0.11	0.25	0.13	0.00	0.17	0.00	0.29	0.14
8	0.00	0.11	0.00	0.82	0.00	0.02	0.40	0.00	0.42	0.00	0.06	0.39
9	0.00	0.46	0.00	0.08	0.00	0.00	0.25	0.00	0.40	0.00	0.05	0.00
10	0.00	0.37	0.00	0.03	0.17	0.05	0.26	0.00	0.53	0.00	0.00	0.00
11	0.00	0.09	0.00	0.81	0.20	0.56	0.04	0.00	0.04	0.00	0.00	0.00
12	0.00	0.01	0.00	0.78	0.35	0.76	0.00	0.00	0.00	0.21	0.00	0.03
13	0.23	0.33	0.02	0.77	0.21	0.00	0.01	0.00	0.00	0.01	0.00	0.00
14	0.60	0.15	0.28	0.27	0.33	0.00	0.01	0.00	0.00	0.00	0.00	0.00
15	0.04	0.21	0.42	0.41	0.01	0.01	0.00	0.00	0.32	0.03	0.00	0.15
16	0.90	0.69	0.38	0.01	0.30	0.07	0.01	0.01	0.26	0.00	0.00	0.43
17	0.70	0.57	0.01	0.08	0.01	0.04	0.00	0.02	0.00	0.00	0.00	0.17
18	0.09	0.42	0.00	0.01	0.00	0.00	0.01	0.13	0.00	0.00	0.00	0.59
19	0.00	0.77	0.40	0.00	0.01	0.00	0.00	0.42	0.01	0.00	0.00	0.75
20	0.00	0.35	0.24	0.00	0.00	0.05	0.08	0.06	0.12	0.00	0.00	0.02
21	0.19	0.32	0.51	0.00	0.00	0.03	1.05	0.10	0.00	0.00	0.00	0.14
22	0.01	0.57	0.08	0.00	0.01	0.18	0.00	0.29	0.00	0.00	0.05	0.00
23	1.45	0.07	0.00	0.00	0.04	0.02	0.15	0.15	0.00	0.00	0.00	0.20
24	0.01	0.20	0.00	0.44	0.17	0.01	0.01	0.00	0.00	0.00	0.00	0.02
25	0.23	0.21	0.01	0.13	0.05	0.58	0.00	0.13	0.00	0.00	0.00	0.01
26	1.09	1.16	0.00	0.00	0.45	0.04	0.24	0.58	0.00	0.00	0.06	0.24
27	0.00	0.00	0.00	0.00	0.12	0.00	0.27	0.08	0.00	0.00	0.00	0.02
28	0.09	0.01	0.00	0.00	0.00	0.39	0.11	1.12	0.00	0.00	0.00	0.05
29	0.52	0.01	0.07	0.00		0.71	0.24	0.25	0.00	0.00	0.00	0.00
30	0.32	0.04	0.00	0.26		0.20	0.14	0.05	0.00	0.00	0.00	0.00
31	0.02		0.34	0.04		0.00		0.47		0.00	0.75	
Max. daily total	1.45	1.38	0.51	0.82	0.45	0.76	1.05	1.12	0.62	0.21	0.75	0.75
Monthly total	6.75	9.75	2.79	6.32	3.10	4.18	4.51	5.13	3.67	0.38	1.26	3.88
Hist. monthly total ^a	4.50	7.23	5.96	5.87	3.59	4.39	3.32	3.06	1.97	0.84	1.36	2.30

^a Historical average monthly precipitation totals measured at rain gage 02V from October 1995 through September 2010

Table B-4. Summary of monthly precipitation totals in inches by water year.
Data are from precipitation station 02V.

Month\Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVG
October	6.36	8.10	5.48	4.43	3.35	3.75	5.53	0.88	7.13	3.44	2.90	2.47	4.59	2.28	6.75	4.50
November	9.62	7.20	4.41	7.63	11.33	3.76	10.24	2.97	5.92	4.46	6.06	13.67	3.65	7.80	9.75	7.23
December	6.96	10.47	3.62	7.33	5.19	2.65	6.05	5.21	4.10	5.52	6.44	8.09	9.67	5.37	2.79	5.96
January	6.60	7.36	8.77	6.35	4.11	3.10	5.43	6.79	6.23	2.80	9.67	4.75	5.14	4.64	6.32	5.87
February	7.92	2.64	2.94	6.17	5.07	2.79	4.74	2.14	3.02	1.96	3.33	3.41	2.82	1.84	3.10	3.59
March	2.64	8.78	4.29	3.96	4.25	3.32	3.59	5.08	2.32	3.82	2.13	6.40	5.45	5.71	4.18	4.39
April	6.28	5.90	2.09	2.14	2.83	3.77	3.17	3.30	0.87	3.40	2.48	2.37	3.43	3.23	4.51	3.32
May	4.40	4.22	3.42	2.88	3.70	2.02	1.32	1.82	3.65	4.39	2.38	2.11	0.11	4.39	5.13	3.06
June	0.56	3.28	2.04	2.70	1.26	2.43	0.54	0.54	1.28	3.83	1.97	2.23	2.36	0.80	3.67	1.97
July	0.96	1.96	0.36	1.83	0.29	1.47	0.13	0.01	0.57	1.23	0.17	1.88	1.31	0.10	0.38	0.84
August	1.82	1.62	0.27	0.99	0.49	2.03	0.43	0.44	3.86	0.57	0.47	1.83	3.53	0.80	1.26	1.36
September	2.54	3.42	1.19	1.07	3.24	0.69	0.97	1.87	3.21	2.60	2.16	2.85	1.25	3.49	3.88	2.30
Total	56.66	64.95	38.88	47.48	45.11	31.78	42.14	31.05	42.16	38.02	40.16	52.06	43.31	40.45	51.72	44.40

Appendix C. Levels of biological condition for BIBI scores

Table C-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 D. BBC-52 wetland vegetation strata

Table D-1. BBC-52 plot vegetation strata by year.

Efforts were made to use the original 2000 strata classification during vegetation surveys; however, six exceptions did occur, which are highlighted in this table. In each case, a different size plot was measured than in other years.

Quadrat	2000	2002	2004	2006	2008	2010
T1A	Forest	Forest	Forest	Forest	Forest	Forest
T1B	Forest	Forest	Forest	Forest	Forest	Forest
T1C	Herb	Herb	Herb	Herb	Herb	Herb
T1D	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T1E	Forest	Forest	Forest	Forest	Forest	Forest
T2A	Forest	Forest	Forest	Forest	Forest	Forest
T2B	Herb	Shrub	Shrub	Shrub	Shrub	Shrub
T2C	Shrub	Shrub	Shrub	Herb	Shrub	Shrub
T2D	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T2E	Forest	Shrub	Forest	Forest	Forest	Forest
T3A	Forest	Forest	Forest	Forest	Forest	Forest
T3B	Forest	Forest	Forest	Forest	Forest	Forest
T3C	Herb	Herb	Herb	Herb	Herb	Herb
T3D	Herb	Herb	Herb	Herb	Herb	Herb
T3E	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T3F	Forest	Forest	Forest	Forest	Forest	Forest
T4A	Forest	Forest	Forest	Forest	Forest	Forest
T4B	Forest	Forest	Forest	Forest	Forest	Forest
T4C	Herb	Herb	Herb	Herb	Herb	Herb
T4D	Shrub	Herb	Shrub	Shrub	Shrub	Shrub
T4E	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T4F	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T4G	Forest	Forest	Forest	Forest	Forest	Forest
T5A	Forest	Forest	Forest	Forest	Forest	Forest
T5B	Forest	Forest	Forest	Forest	Forest	Forest
T5C	Herb	Herb	Herb	Herb	Herb	Herb
T5D	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T5E	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T5F	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T5G	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T5H	Forest	Forest	Forest	Forest	Forest	Forest
T5I	Forest	Forest	Forest	Forest	Forest	Forest
T6A	Forest	Forest	Forest	Forest	Forest	Forest
T6B	Forest	Forest	Forest	Forest	Forest	Forest
T6C	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T6D	Shrub	Shrub	Shrub	Shrub	Shrub	Shrub
T6E	Herb	Herb	Herb	Herb	Herb	Herb
T6F	Herb	Herb	Herb	Herb	Herb	Herb
T6G	Shrub	Shrub	Shrub	Herb	Shrub	Shrub
T6H	Forest	Forest	Forest	Shrub	Forest	Forest
T6I	Forest	Forest	Forest	Forest	Forest	Forest

Appendix E. BBC-52 lumped taxa

Table E-1. BBC-52 lumped taxa.

The following taxa were lumped together for the purposes of data analysis to reduce differences based on staff expertise, level of taxonomic effort, etc. Table continued next page.

Roll Up Code	Common Name	Genus species
Carex spp.	beaked sedge	<i>Carex rostrata</i>
	Dewey's sedge	<i>Carex deweyana</i>
	sedge	<i>Carex spp.</i>
	slough sedge	<i>Carex obnupta</i>
Epilobium spp.	fireweed	<i>Epilobium angustifolium</i>
	Watson's willowherb	<i>Epilobium ciliatum</i>
	willowherb	<i>Epilobium spp.</i>
Galium spp	bedstraws	<i>Galium spp</i>
	Northern wild licorice	<i>Galium kamtschaticum</i>
	sweet scented bedstraw	<i>Galium trifolium</i>
Glyceria spp.	American mannagrass	<i>Glyceria grandis</i>
	mannagrass	<i>Glyceria spp.</i>
	Northern mannagrass	<i>Glyceria borealis</i>
	tall mannagrass	<i>Glyceria elata</i>
Gramineae	creeping bentgrass	<i>Agrostis stolonifera</i>
	foxtail grass	<i>Alopecurus spp</i>
	grasses	<i>Gramineae</i>
JUEF	grooved rush	<i>Juncus patens</i>
	soft rush	<i>Juncus effusus</i>
Juncus spp.	pointed rush	<i>Juncus oxymersis</i>
	rush	<i>Juncus spp.</i>
	tapered rush	<i>Juncus acuminatus</i>
Luzula spp.	small flowered woodrush	<i>Luzula parviflora</i>
	wood rush	<i>Luzula spp.</i>
moss	bottle moss	<i>Amphidium lapponicum</i>
	moss	
	sphagnum moss	<i>Sphagnum spp.</i>
	non-sphagnum moss	<i>non-sphagnum moss</i>
PISI	Sitka spruce	<i>Picea sitchensis</i>
	spruce	<i>Picea sp.</i>
Polygonum spp	lady's thumb	<i>Polygonum persicaria</i>
	pondweed	<i>Polygonum spp</i>

Table E-1. BBC-52 lumped taxa (cont'd).

Roll Up Code	Common Name	Genus species
Potamogeton spp	broad-leaf pondweed	<i>Potamogeton spp</i>
	floating leaved pondweed	<i>Potamogeton natans</i>
	narrow-leaved pondweed	<i>Potamogeton foliosis</i>
	ribbon leaf pondweed	<i>Potamogeton epihydrus</i>
	small pondweed	<i>Potamogeton pusillus</i>
Pyrola spp.	liver leaf wintergreen	<i>Pyrola asarifolia</i>
	one-sided wintergreen	<i>Pyrola secunda</i>
	wintergreen	<i>Pyrola spp.</i>
Ranunculus spp	creeping buttercup	<i>Ranunculus repens</i>
	white water-buttercup	<i>Ranunculus aquatilis</i>
Ribes spp	black swamp gooseberry	<i>Ribes lacustre</i>
	currant	<i>Ribes spp</i>
	red-flowering currant	<i>Ribes sanguineum</i>
Rosa spp	bald hip rose	<i>Rosa gymnocarpa</i>
	rose	<i>Rosa spp</i>
Salix spp.	hooker's willow	<i>Salix hookeriana</i>
	Pacific willow	<i>Salix lucida</i>
	willow	<i>Salix spp.</i>
Sorbus spp	European mountain ash	<i>Sorbus aucuparia</i>
	mountain ash	<i>Sorbus spp</i>
	Sitka mountain ash	<i>Sorbus sitchensis</i>
Sparganium spp	burreed	<i>Sparganium spp</i>
	narrowleaf burreed	<i>Sparganium emersum</i>
Typha spp.	cattail	<i>Typha spp.</i>
	common cattail	<i>Typha latifolia</i>
Veronica spp	American brooklime	<i>Veronica americana</i>
	marsh speedwell	<i>Veronica scutellata</i>
	speedwell	<i>Veronica spp</i>
Viola spp	darkwoods violet	<i>Viola orbiculata</i>
	hookedspur violet	<i>Viola adunca</i>
	violet	<i>Viola spp</i>

Appendix F. BBC-52 vegetation list

Table F-1. BBC-52 vegetation list.

The following vascular plants were observed at least once during even year vegetation surveys at the BBC-52 wetland (2000, 2002, 2004, 2006, 2008, and 2010). Table continued next page.

Scientific Name	Common Name	Code
<i>Acer circinatum</i>	vine-maple	ACCI
<i>Acer macrophyllum</i>	big-leaf maple	ACMA
<i>Achlys triphylla</i>	vanillaleaf	ACTR
<i>Agrostis stolonifera</i>	creeping bentgrass	AGST
<i>Alnus rubra</i>	red alder	ALRU
<i>Alopecurus spp</i>	foxtail grass	Alopecurus spp
<i>Athyrium felix-femina</i>	lady fern	ATFF
<i>Atropa belladonna</i>	deadly nightshade	ATBE
<i>Blechnum spicant</i>	deer fern	BLSP
<i>Brasenia schreberi</i>	watershield	BRSC
<i>Callitriche spp</i>	water-starwort	Callitriche spp
<i>Cardamine hirsuta</i>	hairy bittercress	CAHI
<i>Carex deweyana</i>	Dewey's sedge	CADE
<i>Carex obnupta</i>	slough sedge	CAOB
<i>Carex rostrata</i>	beaked sedge	CARO
<i>Carex spp.</i>	sedge	Carex spp.
<i>Ceratophyllum demersum</i>	coontail	CEDE
<i>Cirsium spp.</i>	plume thistles	Cirsium spp.
<i>Claytonia sibirica</i>	Siberian miner's lettuce	CLSI
<i>Cornus stolonifera</i>	red osier dogwood	COST
<i>Dicentra formosa</i>	Pacific bleeding heart	DIFO
<i>Drosera rotundifolia</i>	round-leaved sundew	DRRO
<i>Dryopteris expansa</i>	wood fern	DREX
<i>Epilobium angustifolium</i>	fireweed	EPAN
<i>Epilobium ciliatum</i>	Watson's willowherb	EPCI
<i>Epilobium spp.</i>	willowherb	Epilobium spp.
<i>Galium kamtschaticum</i>	Northern wild licorice	GAKA
<i>Galium spp</i>	bedstraws	Galium spp
<i>Galium triflorum</i>	sweet scented bedstraw	GATR
<i>Gaultheria shallon</i>	salal	GASH
<i>Geum spp.</i>	avens	Geum spp.
<i>Glyceria borealis</i>	Northern mannagrass	GLBO
<i>Glyceria elata</i>	tall mannagrass	GLEL
<i>Glyceria grandis</i>	American mannagrass	GLGR
<i>Glyceria spp.</i>	mannagrass	Glyceria spp.
<i>Gramineae</i>	grasses	Gramineae
<i>Hedera Helix</i>	English ivy	HEHE
<i>Hemitomes congestum</i>	gnome-plant	HECO
<i>Holodiscus discolor</i>	oceanspray	HODI
<i>Ilex aquifolium</i>	holly	ILAQ
<i>Impatiens capensis</i>	jewelweed	IMCA

Table F-1. BBC-52 vegetation list (cont'd and continued next page).

Scientific Name	Common Name	Code
<i>Juncus acuminatus</i>	tapered rush	JUAC
<i>Juncus effusus</i>	soft rush	JUEF
<i>Juncus oxymeris</i>	pointed rush	JUOX
<i>Juncus patens</i>	grooved rush	JUPA
<i>Juncus spp.</i>	rush	Juncus spp.
<i>Juncus supiniformis</i>	spreading rush	JUSU
<i>Kalmia microphylla ssp. Occidentalis</i>	swamp laurel	KAMI
<i>Ledum groenlandicum</i>	Labrador tea	LEGR
<i>Lonicera involucrata</i>	black twinberry	LOIN
<i>Ludwigia palustris</i>	water purslane	LUPA
<i>Luzula parviflora</i>	small flowered woodrush	LUPAR
<i>Luzula spp.</i>	wood rush	Luzula spp.
<i>Lycopus uniflorus</i>	northern bugleweed	LYUN
<i>Lysichiton americanum</i>	skunk cabbage	LYAM
<i>Mahonia nervosa</i>	dull oregon grape	MANE
<i>Maianthemum dilatatum</i>	false lily-of-the-valley	MADI
<i>Malus fusca</i>	Western crabapple	MAFU
<i>Menziesia ferruginea</i>	false azalea	MEFE
<i>Mycelis muralis</i>	wall lettuce	MYMU
<i>Myosotis scorpioides</i>	water forget-me-not	MYSC
<i>Myrica gale</i>	sweet gale	MYGA
<i>Nuphar luteum</i>	yellow pond lily	NULU
<i>Oemleria cerasiformis</i>	Indian plum	OECE
<i>Oxycoccus oxycoccus</i>	bog cranberry	OXOX
<i>Phalaris arundinacea</i>	reed canarygrass	PHAR
<i>Physocarpus capitatus</i>	Pacific ninebark	PHCA
<i>Picea sitchensis</i>	Sitka spruce	PISI
<i>Picea sp.</i>	spruce	Picea sp.
<i>Plantago sp.</i>	plantains	Plantago sp.
<i>Polygonum amphibium</i>	water ladysthumb/smartweed	POAM
<i>Polygonum persicaria</i>	lady's thumb	POPE
<i>Polygonum spp</i>	pondweed	Polygonum spp
<i>Polypodium glycyrrhiza</i>	licorice fern	POGL
<i>Polystichum munitum</i>	sword fern	POMU
<i>Populus balsamifera</i>	black cottonwood	POBA
<i>Potamogeton natans</i>	floating leaved pondweed	PONA
<i>Potamogeton epihydrus</i>	ribbon leaf pondweed	POEP
<i>Potamogeton foliosis</i>	narrow-leaved pondweed	POFO
<i>Potamogeton pusillus</i>	small pondweed	POPU
<i>Potamogeton spp</i>	broad-leaf pondweed	Potamogeton spp
<i>Prunus emarginata</i>	bitter cherry	PREM
<i>Pseudotsuga menziesii</i>	Douglas-fir	PSME
<i>Pteridium aquilinum</i>	bracken fern	PTAQ
<i>Pyrola asarifolia</i>	liver leaf wintergreen	PYAS
<i>Pyrola secunda</i>	one-sided wintergreen	PYSE
<i>Pyrola spp.</i>	wintergreen	Pyrola spp.

Table F-1. BBC-52 vegetation list (cont'd).

Scientific Name	Common Name	Code
<i>Ranunculus aquatilis</i>	white water-buttercup	RAAQ
<i>Ranunculus repens</i>	creeping buttercup	RARE
<i>Rhamnus purshiana</i>	cascara	RHPU
<i>Ribes lacustre</i>	black swamp gooseberry	RILA
<i>Ribes sanguineum</i>	red-flowering currant	RISA
<i>Ribes spp</i>	currant	Ribes spp
<i>Rosa gymnocarpa</i>	bald hip rose	ROGY
<i>Rosa spp</i>	rose	Rosa spp
<i>Rubus laciniatus</i>	evergreen blackberry	RULA
<i>Rubus leucodermis</i>	black raspberry	RULE
<i>Rubus spectabilis</i>	salmonberry	RUSP
<i>Rubus ursinus</i>	trailing blackberry	RUUR
<i>Salix hookeriana</i>	hooker's willow	SAHO
<i>Salix lucida</i>	Pacific willow	SALU
<i>Salix spp.</i>	willow	Salix spp.
<i>Sambucus racemosa</i>	red elderberry	SARA
<i>Scirpus microcarpus</i>	small-fruited bulrush	SCMI
<i>Sorbus aucuparia</i>	European mountain ash	SOAU
<i>Sorbus sitchensis</i>	Sitka mountain ash	SOSI
<i>Sorbus spp</i>	mountain ash	Sorbus spp
<i>Sparganium emersum</i>	narrowleaf burreed	SPEM
<i>Sparganium spp</i>	burreed	Sparganium spp
<i>Spirea douglasii</i>	spirea, hardhack	SPDO
<i>Stellaria spp</i>	starwort	Stellaria spp
<i>Symphoricarpos albus</i>	snowberry	SYAL
<i>Thuja plicata</i>	western red cedar	THPL
<i>Tiarella trifoliata</i>	foam flower	TITR
<i>Trientalis latifolia</i>	broad-leaved starflower	TRLA
<i>Trillium ovatum</i>	western trillium	TROV
<i>Tsuga heterophylla</i>	western hemlock	TSHE
<i>Typha latifolia</i>	common cattail	TYLA
<i>Typha spp.</i>	cattail	Typha spp.
<i>Urticularia spp.</i>	bladderwort	Urticularia spp
<i>Vaccinium oxycoccos</i>	small cranberry	VAOX
<i>Vaccinium parvifolium</i>	red huckleberry	VAPA
<i>Vancouveria hexandra</i>	inside out flower	VAHE
<i>Veronica americana</i>	American brooklime	VEAM
<i>Veronica scutellata</i>	marsh speedwell	VESC
<i>Veronica spp</i>	speedwell	Veronica spp
<i>Viola adunca</i>	hookedspur violet	VIAD
<i>Viola orbiculata</i>	darkwoods violet	VIOR
<i>Viola spp</i>	violet	Viola spp

Appendix G. BBC-52 invasive species locations

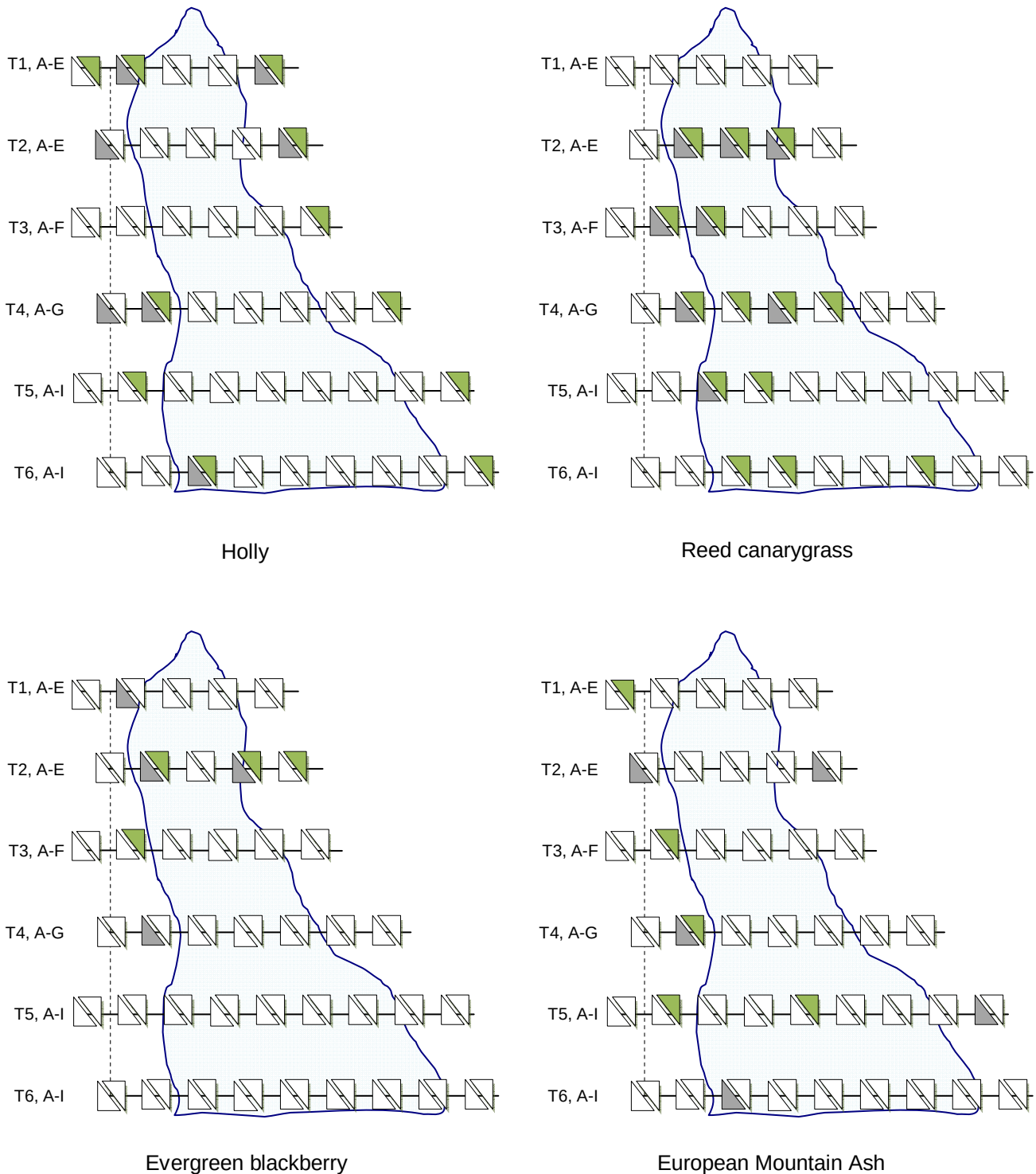


Figure G-1. BBC-52 invasive species locations.

A gray triangle indicates that a species was observed at the quadrat during predevelopment (2000-2004) and a green triangle indicates the species was observed during construction (2006-2010).

Appendix H. 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 increased nutrient inputs through sediment transport (Beak Consultants Incorporated 1995). However, these impacts were predicted to be mitigated effectively 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 the wetlands than in streams (Figure H-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 H-1). This site, which had 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 H-2), and there is little opportunity for the slow moving wetland water to become aerated as it transitions into flowing water.

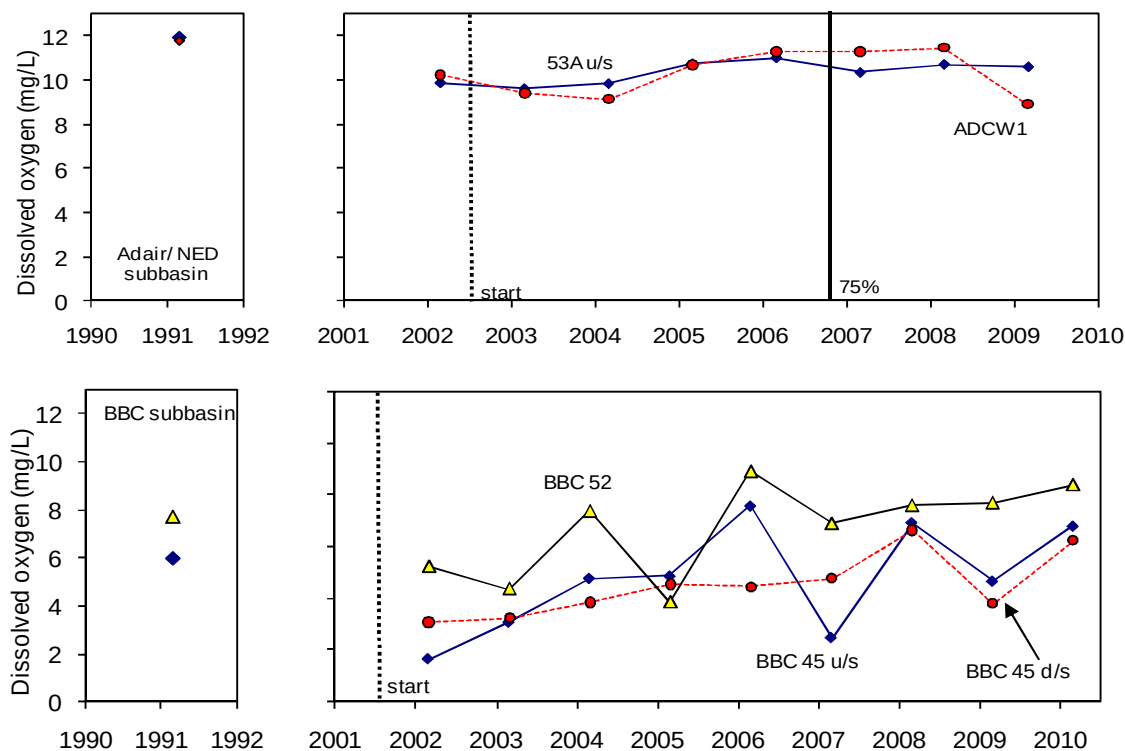


Figure H-1. Average dissolved oxygen (1991, 2002-2010).

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 23 for locations. (Continued next page)

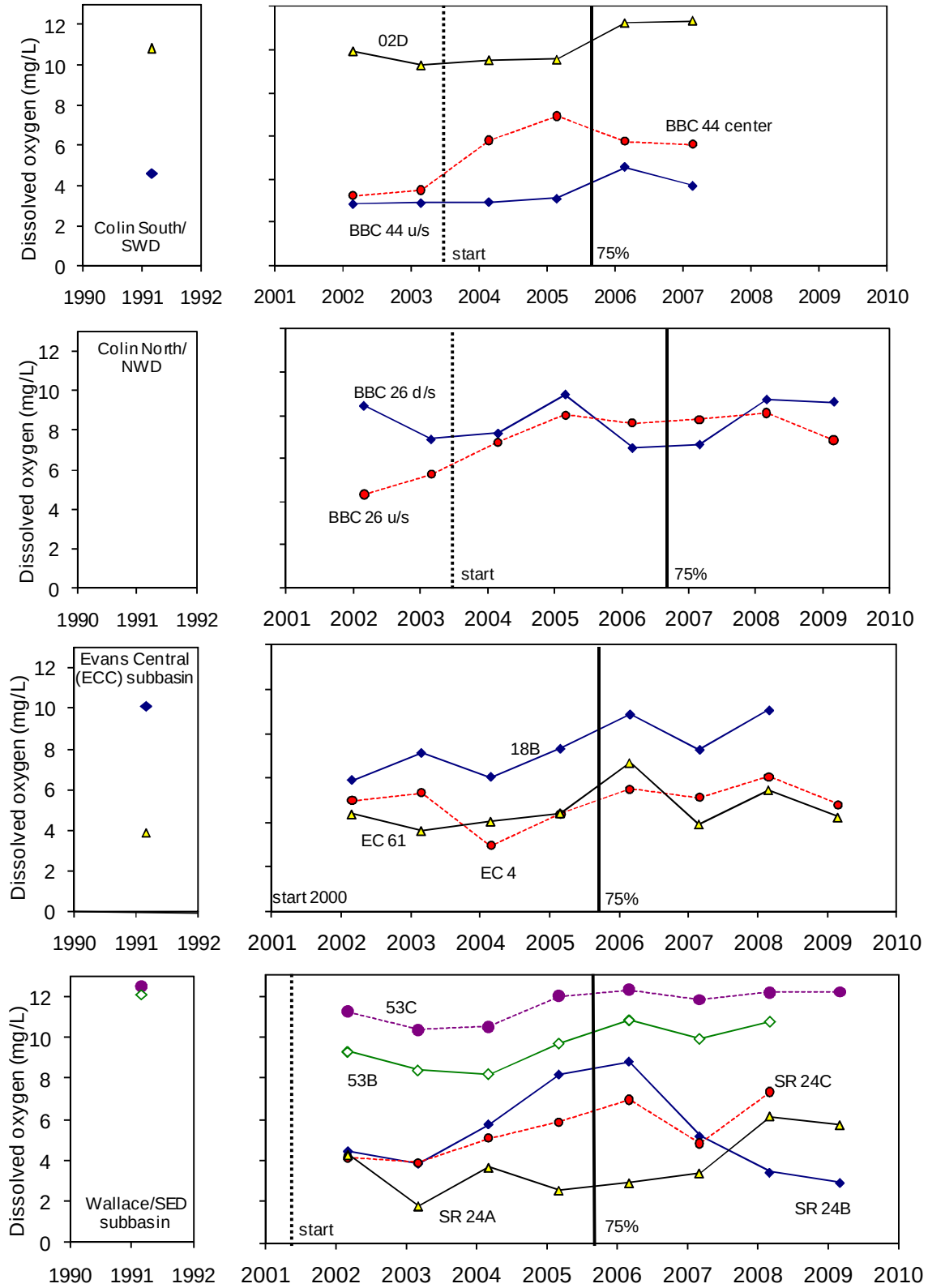


Figure H-1. (Cont'd) Average dissolved oxygen. (Continued next page)

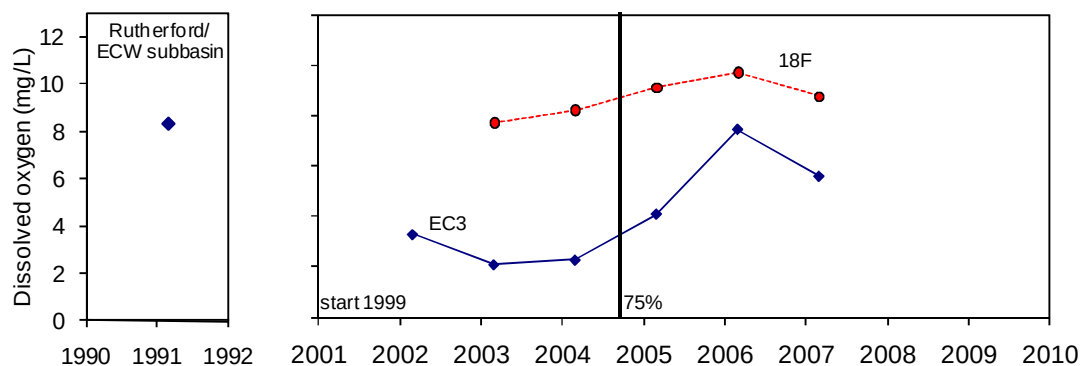


Figure H-1. (Cont'd) Average dissolved oxygen.

Although wetland oxygenation of the water continued to be low, no further violations of the State dissolved oxygen standard were observed at the stream sites during the winter months of 2008-2010. The list below represents the entirety of violations found during the monitoring period (Table H-1).

Table H-1. Stream dissolved oxygen levels below 6.5 mg/L, 2002-2010.

6.5 mg/L is the state standard for salmonid rearing and migration (Washington Department of Ecology 2006).

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 H-2. The south weir.

The south weir, gaging site 18B, separates wetland EC-3 from Evans Creek Central. Water quality samples were 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 time⁸². Nonetheless, 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 H-1).

⁸² 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 I. 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 I-1). Spikes in turbidity were seen in most subbasins in 2005 and in some subbasins for 2007; the spikes are most likely related to storm events.

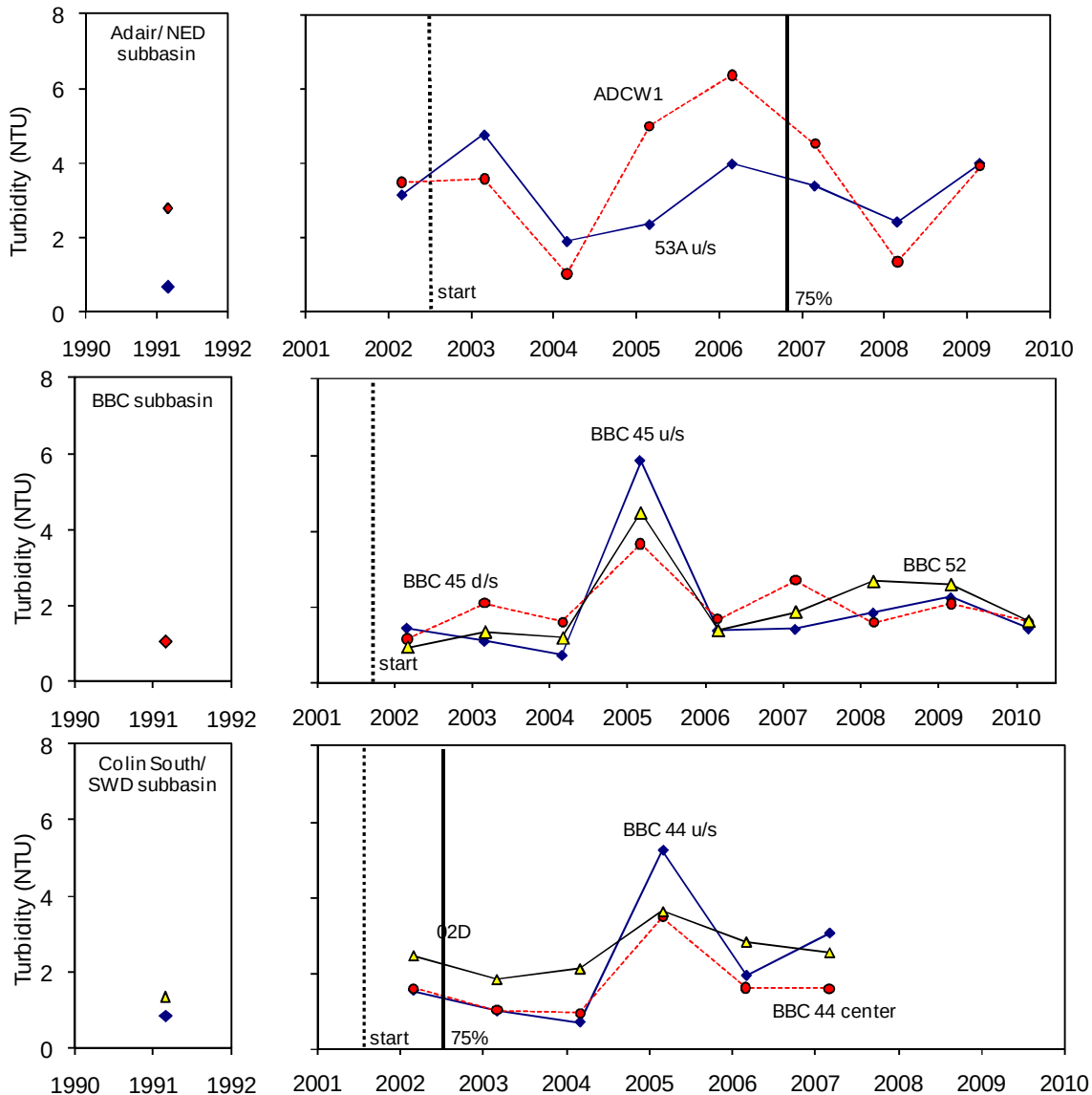


Figure I-1. Average annual turbidity (1991, 2002-2010).

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 percent buildout was reached within the subbasin. See Figure 23 in the main body of the report for locations. (Continued next page)

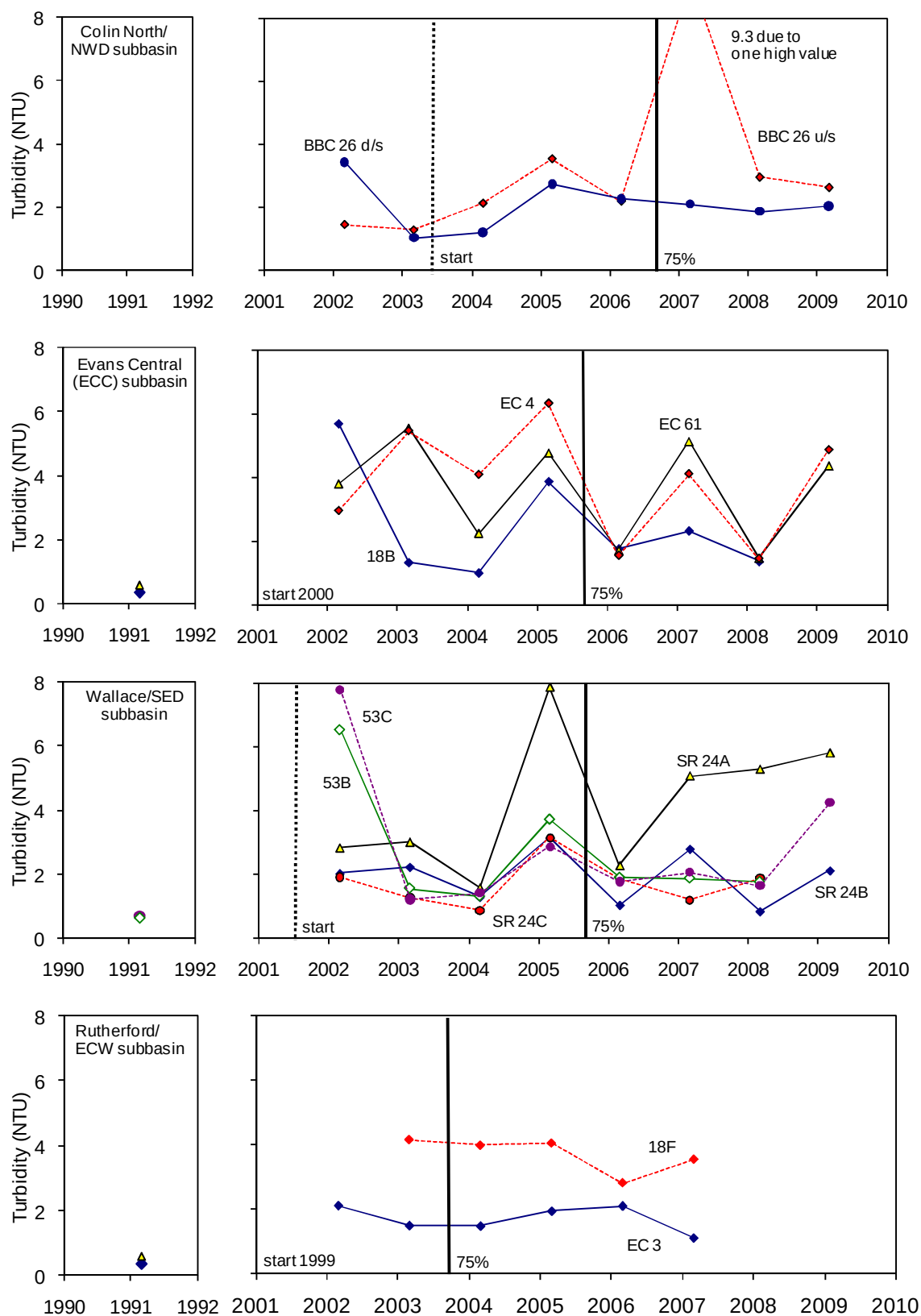


Figure I-1. (Cont'd) Average annual turbidity (1991, 2002-2010).

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 I-1). No exceedances were recorded in 2008-2010.

Table I-2. 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	Turbidity (NTU)
BBC-26 u/s	2/27/07	23.9 ⁸³
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

In addition to January through April point sampling of turbidity, attempts were made to monitor turbidity at several continuous stream gaging locations, but these were ceased in 2005 because of equipment difficulties.

⁸³ The highest level ever observed at the UPDs (23.9 NTU) was at wetland BBC-26 u/s on February 27, 2007 when 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. The pumps were immediately turned off, and this violation was reported to onsite UPD inspector Bob Kelley, 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 by 5/1/07 had dropped to 1.45 NTU

Appendix J. Metals data

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 UPD 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 1990s⁸⁴.

Metals monitoring was not required in the Trilogy or Redmond Ridge monitoring plans (King County 1999, 2001); however, total metals data became available when hardness measurements were added in 2006 and these data were reported in the 2007 Monitoring Report (see Appendix T, Table T-2 of the 2007 UPD Monitoring Report (King County 2010)). Most Washington state toxics criteria for metals (WAC Chapter 173-201A 2003) are based on dissolved concentrations, however prior to the 2009 sampling only total metals data were available for the UPD monitoring locations. Because of elevated levels of total copper and zinc observed at some locations, grab samples were collected in 2009 during January to April sampling for dissolved metals analysis at 8 water quality sampling stations (53C, ADCW1, BBC-26d/s, BBC26-u/s, BBC-45d/s, BBC-45 u/s, SR-24A, and SR-24B). In 2010, dissolved metals analysis was reduced to BBC-45d/s and BBC-45u/s based on results of the 2009 sampling events.

Results of inductively coupled plasma (ICP) analysis of metal/metalloid particulates for aluminum, copper, iron, and zinc are shown in Table J-1. There are no state standards for aluminum or iron, but concentrations were above EPA chronic toxicity levels for aluminum at 53C (3), ADCW1 (3), BBC-45d/s (1), and BBC-45u/s (3), and SR-24A (3) and for iron at SR-24A (2). Copper was only detected 3 times, all at BBC-45d/s and in each instance levels exceeded state acute toxicity thresholds. Zinc was detected 7 times at 53C or BBC-45d/s and exceeded chronic or acute thresholds three times at BBC-45d/s. Results for other metal/metalloid particulates⁸⁵ did not have any exceedances of state or federal standards.

⁸⁴ 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).

⁸⁵ The ICP tests included antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, lead, lithium, manganese, molybdenum, nickel, phosphorus, potassium, selenium, silver, sodium, strontium, sulfur, thallium, tin, titanium, and vanadium.

Table J-1. Metal concentrations relative to state and federal toxic criteria (2009 and 2010).

Copper and zinc criteria are hardness dependent. Concentrations above EPA or WA State standards are highlighted in orange (chronic criteria); or yellow (acute criteria). Abbreviations include: MDL - method detection limit; RDL - reporting detection limit; Tot - total; Dis - dissolved; Qual - Qualifications; Chr - chronic.

LOCATOR	Date	Hardness (mg CaCO ₃ /L)	Aluminum (µg/L)				Copper (µg/L)				Iron (µg/L)				Zinc (µg/L)			
			Qual	Tot Al	EPA Acute	EPA Chr	Qual	Dis Cu	WA Acute	WA Chr	Qual	Dis Fe	EPA Chr	Qual	Dis Zn	WA Acute	WA Chr	
53C	28-Jan-09	12.5	<RDL	230	750	87	<MDL		2.40	1.92	<RDL	170	1000	<RDL	12	19.65	17.95	
53C	25-Feb-09	13.2		1440	750	87	<MDL		2.53	2.01		264	1000	<RDL	9.5	20.58	18.79	
53C	30-Apr-09	15.5	<RDL	310	750	87	<MDL		2.94	2.31	<RDL	220	1000	<RDL	14	23.58	21.53	
ADCW1	28-Jan-09	28.8	<RDL	290	750	87			5.27	3.92			1000			39.86	36.40	
ADCW1	25-Feb-09	28.9	<RDL	200	750	87			5.28	3.93			1000			39.98	36.51	
ADCW1	30-Apr-09	29.6	<RDL	120	750	87			5.40	4.01			1000			40.80	37.25	
BBC26D/S	28-Jan-09	26.0	<MDL		750	87			4.78	3.59			1000			36.55	33.38	
BBC26D/S	25-Feb-09	25.3	<MDL		750	87			4.66	3.51			1000			35.72	32.61	
BBC26D/S	30-Apr-09	28.0	<MDL		750	87			5.13	3.82			1000			38.92	35.54	
BBC26U/S	28-Jan-09	23.4	<MDL		750	87			4.33	3.28			1000			33.43	30.53	
BBC26U/S	25-Feb-09	24.6	<MDL		750	87			4.54	3.42			1000			34.88	31.85	
BBC26U/S	30-Apr-09	22.6	<MDL		750	87			4.19	3.19			1000			32.46	29.64	
BBC45D/S	28-Jan-09	2.7	<MDL		750	87	<MDL		0.57	0.52	<RDL	210	1000	<RDL	5.2	5.40	4.93	
BBC45D/S	25-Feb-09	3.6	<MDL		750	87	<MDL		0.74	0.66	<RDL	200	1000	<MDL		6.83	6.24	
BBC45D/S	30-Apr-09	4.0	<RDL	150	750	87	<RDL	5.9	0.83	0.73	<RDL	220	1000	<RDL	12	7.55	6.89	
BBC45D/S	27-Jan-10	3.4	<RDL	110	750	87			0.70	0.63		255	1000			6.49	5.93	
BBC45D/S	25-Feb-10	3.2	<RDL	100	750	87		4.29	0.66	0.60			1000		11.2	6.18	5.64	
BBC45D/S	26-Apr-10	3.4	<MDL		750	87	<RDL	0.82	0.70	0.63			1000		2.6	6.49	5.93	
BBC45U/S	28-Jan-09	5.9	<RDL	210	750	87			1.19	1.01			1000			10.43	9.53	
BBC45U/S	25-Feb-09	4.9	<RDL	180	750	87			0.99	0.86			1000			8.90	8.13	
BBC45U/S	30-Apr-09	5.4	<RDL	210	750	87			1.09	0.94			1000			9.65	8.81	
BBC45U/S	27-Jan-10	5.2	<RDL	220	750	87			1.05	0.91			1000			9.35	8.54	
BBC45U/S	25-Feb-10	4.7	<RDL	210	750	87			0.96	0.84			1000			8.64	7.89	
BBC45U/S	26-Apr-10	5.3	<RDL	250	750	87			1.07	0.92			1000			9.48	8.66	
SR24A	28-Jan-09	15.7	<RDL	160	750	87	<MDL		2.97	2.33		1750	1000	<MDL		23.84	21.77	
SR24A	25-Feb-09	15.6	<RDL	140	750	87	<MDL		2.96	2.32		1070	1000	<MDL		23.71	21.65	
SR24A	30-Apr-09	18.9	<RDL	160	750	87	<MDL		3.54	2.73		833	1000	<MDL		27.90	25.47	
SR24B	28-Jan-09	16.6	<MDL		750	87	<MDL		3.13	2.45	<RDL	210	1000	<MDL		24.99	22.82	
SR24B	25-Feb-09	16.8	<MDL		750	87	<MDL		3.17	2.47	<RDL	160	1000	<MDL		25.25	23.05	
SR24B	30-Apr-09	17.2	<MDL		750	87	<MDL		3.24	2.52	<RDL	170	1000	<MDL		25.76	23.52	

Appendix K. Summer/fall wetland water quality data

Table K-1. Summer/fall wetland water quality data.

Rtn = routine; Strm = storm; MDL = method detection limit. 1984 data were not noted as routine or storm and the exact sampling location is unknown.

Wetland	Sample Type	Date	Temp (°C)	DO (mg/L)	pH	Cond (µS/cm)	Turbidity (NTU)	Total N (mg/L)	Nitrate + nitrite (mg/L)	Total P (mg/L)	Herbi-cides
BBC-45 d/s	Rtn	4/2/91	8.1	6.8	5.76	18	2.3	0.10	0.01	0.03	
BBC-45 d/s	Rtn	4/30/91	7.5	5.6	5.73	17	0.7	0.26	0.01	0.02	
BBC-45 d/s	Rtn	5/23/91	10.1	1.7	5.69	17	4.7	0.94	0.02	0.06	
BBC-45 d/s	Rtn	6/19/91	11.6	1.2	5.51	17	12.3	1.05	0.01	0.09	
BBC-45 d/s	Rtn	7/30/91	13.2	0.1	5.4	23	6.3	1.50	0.03	0.12	
BBC-45 d/s	Rtn	9/3/91	11.5	0.2	5.37	28	8	1.93	0.01	0.28	
BBC-45 d/s	Rtn	9/24/91	11.3	1.1	5.37	41	6.9	2.25	0.07	0.24	
BBC-45 d/s	Rtn	10/29/91	4.3	2.1	5.6	74	5.4	4.41	0.09	0.23	
BBC-45 d/s	Rtn	11/25/91	7	0.7	5.58	31	14	2.10	0.05	0.27	
BBC-45 d/s	Strm	12/5/91	5.8	0.6	5.86	25	3	1.73	0.03	0.19	
BBC-45 d/s	Rtn	12/26/91	6.2	1.6	5.35	21	1.7	1.16	0.03	0.08	
BBC-45 d/s	Strm	1/27/92	5.8	7.3	6.91	17		0.79	0.01	0.08	
BBC-45 d/s	Rtn	2/5/92	4.9	3.3	5.31	23	0.67	0.47	0.44	0.02	
BBC-45 d/s	Rtn	2/25/92	7.2	5.3	5.85	28	1.73	0.65	0.04	0.06	
BBC-45 d/s	Strm	4/29/92	12.9	2.9	5.14	19	1.1	0.64	0.06	0.03	
BBC-45 d/s	Rtn	9/16/09	18.91	7.8	4.84	24.1	3.94	2.21	<MDL	0.17	<MDL
BBC-45 d/s	Strm	10/26/09	9.37	11.15	4.97	28.8	6.92	1.64	<MDL	0.11	<MDL
BBC-45 d/s	Rtn	8/16/10	19.32	2.4	5.01	17.4		1.10	<MDL	0.08	<MDL
BBC-45 d/s	Strm	8/31/10	14	6.9	5.29	15.6	3.53	0.76	<MDL	0.04	<MDL
BBC-52		3/7/84	4.1	14.8	5.0	25.0	0.9	30.00	0.25	0.01	
BBC-52		5/9/84	6.9	6.6	5.3	21.0	0.5	20.00	0.01	0.02	
BBC-52		10/13/84	6.9	3.6	4.7	28.0					
BBC-52		11/12/84	5.8	6.9	4.5	58.0	1.0	35.00	1.80	0.04	
BBC-52	Rtn	3/26/91	6.7	7.7	5.89	22	1	0.34	0.05	0.02	
BBC-52	Rtn	6/19/91	14.7	3.7	5.99	20	2.7	0.44	0.01	0.03	
BBC-52	Rtn	8/28/91									
BBC-52	Rtn	9/25/91	20.5	8.7		41	3	0.39	0.02	0.06	
BBC-52	Rtn	10/29/91	4.9	7.9	6.05	38	16.3	1.91	0.09	0.08	
BBC-52	Rtn	11/25/91	8	5.1	5.6	55	3	0.39	0.04	0.02	
BBC-52	Strm	12/5/91	6.5	5.2	5.92	31	1.7	0.56	0.05	0.02	
BBC-52	Rtn	12/26/91	6.2	2.1	5.03	25	0.8	0.37	0.15	0.07	
BBC-52	Strm	1/27/92	6.4	7.4	6.84	22	0.9	0.42	0.01	0.03	
BBC-52	Rtn	2/5/92	5.5	2.4	5.27	28	0.7	0.64	0.83	0.01	
BBC-52	Rtn	2/25/92	8.3	9.6	5.68	19	1.1	0.53	0.12	0.02	
BBC-52	Strm	4/29/92	13.5	4.7	5.53	23	2	0.71	0.04	0.03	
BBC-52	Rtn	9/16/09	19.84	9.2	5.79	38.2	1.93	1.08	<MDL	0.04	<MDL
BBC-52	Strm	10/26/09	9.42	7.68	5.05	25.5	2.75	0.71	0.19	0.03	<MDL
BBC-52	Rtn	8/16/10	23.28	4.7	5.29	19.2	N/A	0.85	<MDL	0.04	<MDL
BBC-52	Strm	8/31/10	14.2	6.8	5.67	19.1	2.01	0.84	<MDL	0.05	<MDL

Appendix L. Welcome Lake phosphorus, 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 phosphorus, chlorophyll-a, total nitrogen, Secchi transparency, and temperature.

Total phosphorus appears to have decreased during the period of 1996 through 2009 overall (Figure L-1). However, the regression correlation coefficient of 0.3795 suggests that the linear relationship (gray 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 2009 (red lines).

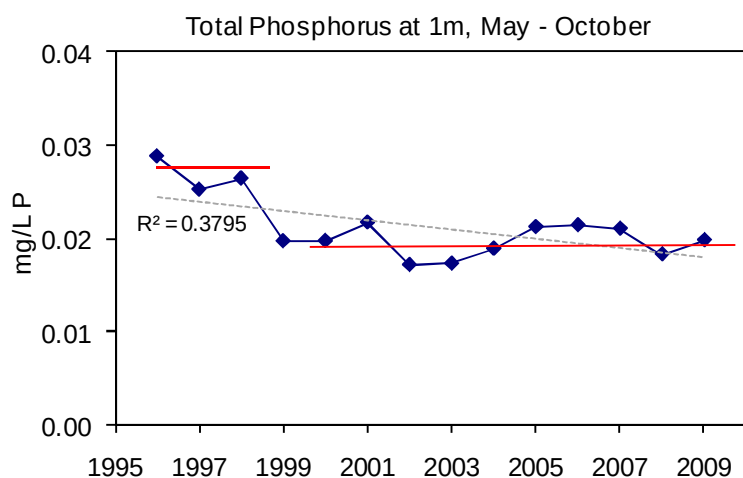


Figure L-1. Welcome Lake mean annual total phosphorus (mg/L). Averaged from biweekly samples collected at 1-m depth from May through October, 1996-2008 and monthly samples collected from June through September 2009.

Chlorophyll-a concentrations have varied widely from 1996 to 2009 (Figure L-2). However, two periods can be defined: higher in 1996-2001 and lower in 2002-2008. The large jump in 2009 is due largely to one very high value in July corresponding to an algae bloom that had extra weight in the seasonal average because of the monthly nature of the samples rather than the biweekly period followed in previous years. No regression correlation coefficient was calculated for the data after visual inspection of the curve.

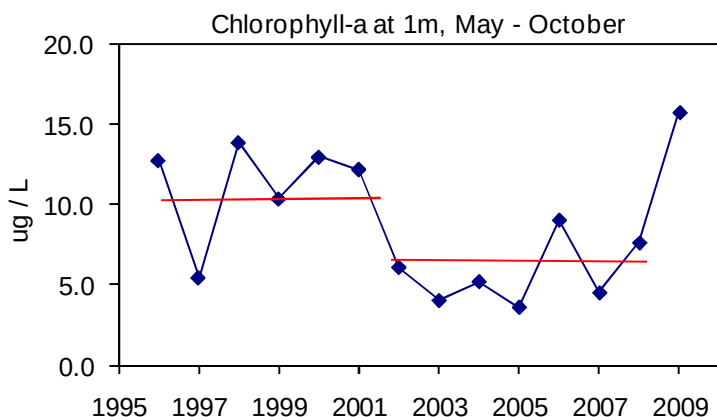


Figure L-2. Welcome Lake mean annual chlorophyll-a (µg/L). Averaged from biweekly samples collected at 1-m depth from May through October, 1996-2008, and monthly samples collected from June through September 2009.

Total nitrogen has remained relatively constant over all years of monitoring, with a different pattern from phosphorus and chlorophyll-a. It may have a slightly decreasing trend that is rather weakly correlated (Figure L-3).

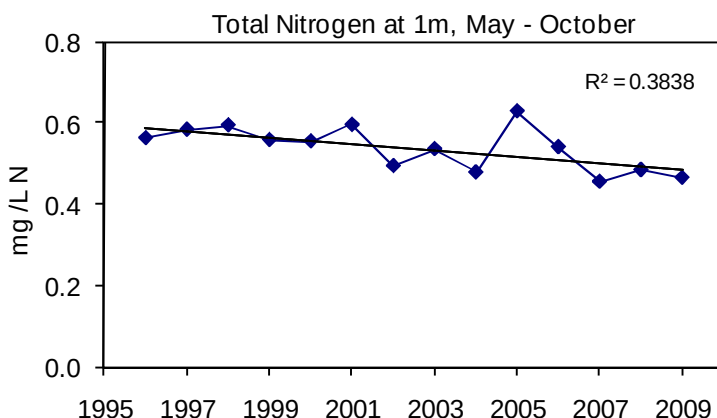


Figure L-3. Welcome Lake mean annual total nitrogen (mg/L). Averaged from biweekly samples collected at 1-m depth from May through October, 1996-2008, and monthly samples collected from June through September 2009.

Secchi transparency has remained relatively constant with small rises and falls (Figure L-4), a pattern that is unrelated to the decreases shown in both phosphorus and chlorophyll-a levels. This difference 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 measurement⁸⁶.

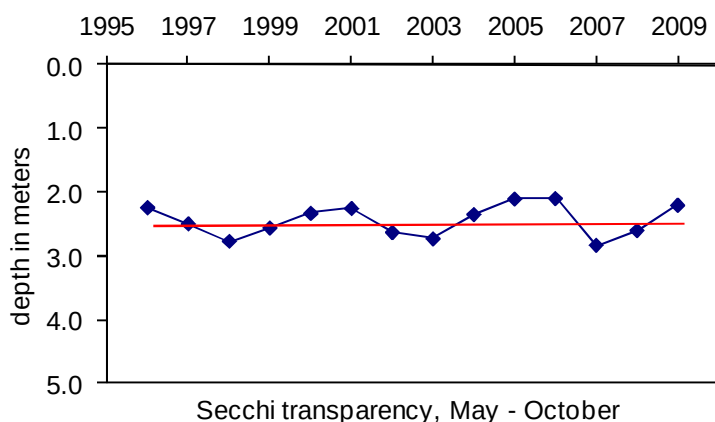


Figure L-4. Welcome Lake mean annual Secchi depth transparency (m). Averaged from biweekly samples collected at 1-m depth from May through October, 1996-2008, and monthly samples collected from June through September 2009.

There are no observable trends in Welcome Lake temperature over the time period of record (1996-2009) with a regression correlation coefficient of less than 0.1 (Figure L-5). The value from 2009 is from a shorter time interval (June to September) that may bias the value relative to the other years with more data, but does not move the data set toward showing a trend away from variation around a stable value.

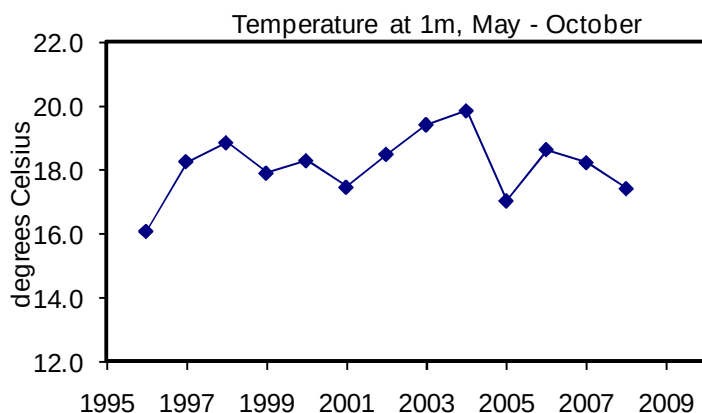


Figure L-5. Welcome Lake mean annual summer temperature (°C). Averaged from biweekly sampling over the deepest part of the lake from May through October, 1996-2008.

⁸⁶ 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 M. Trilogy groundwater levels compared to precipitation

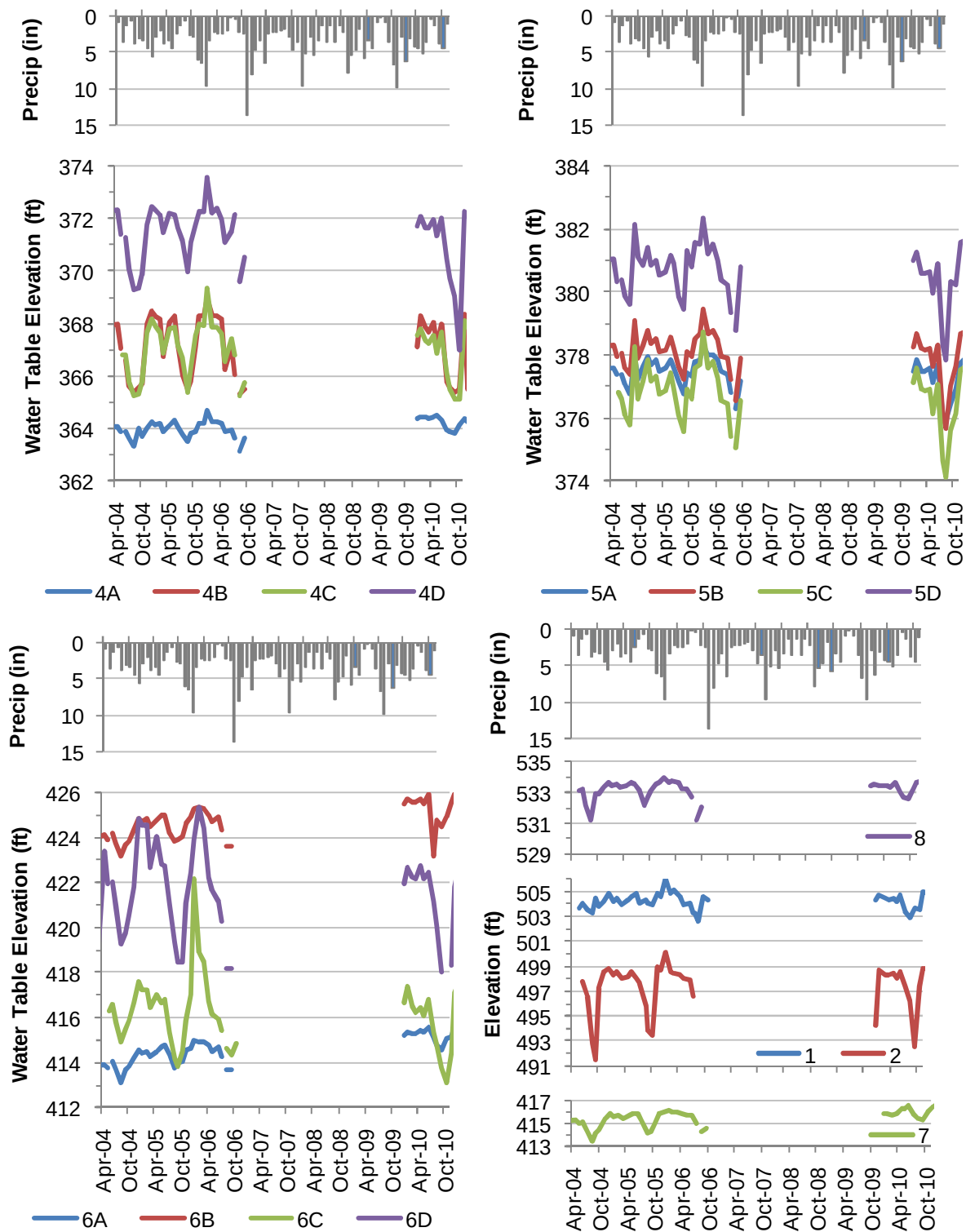


Figure M-1. Monthly precipitation totals and Trilogy groundwater levels by water year (2004-2006 and 2010).

Appendix N. Trilogy groundwater levels (water years 1992, 2005, 2006, and 2010)

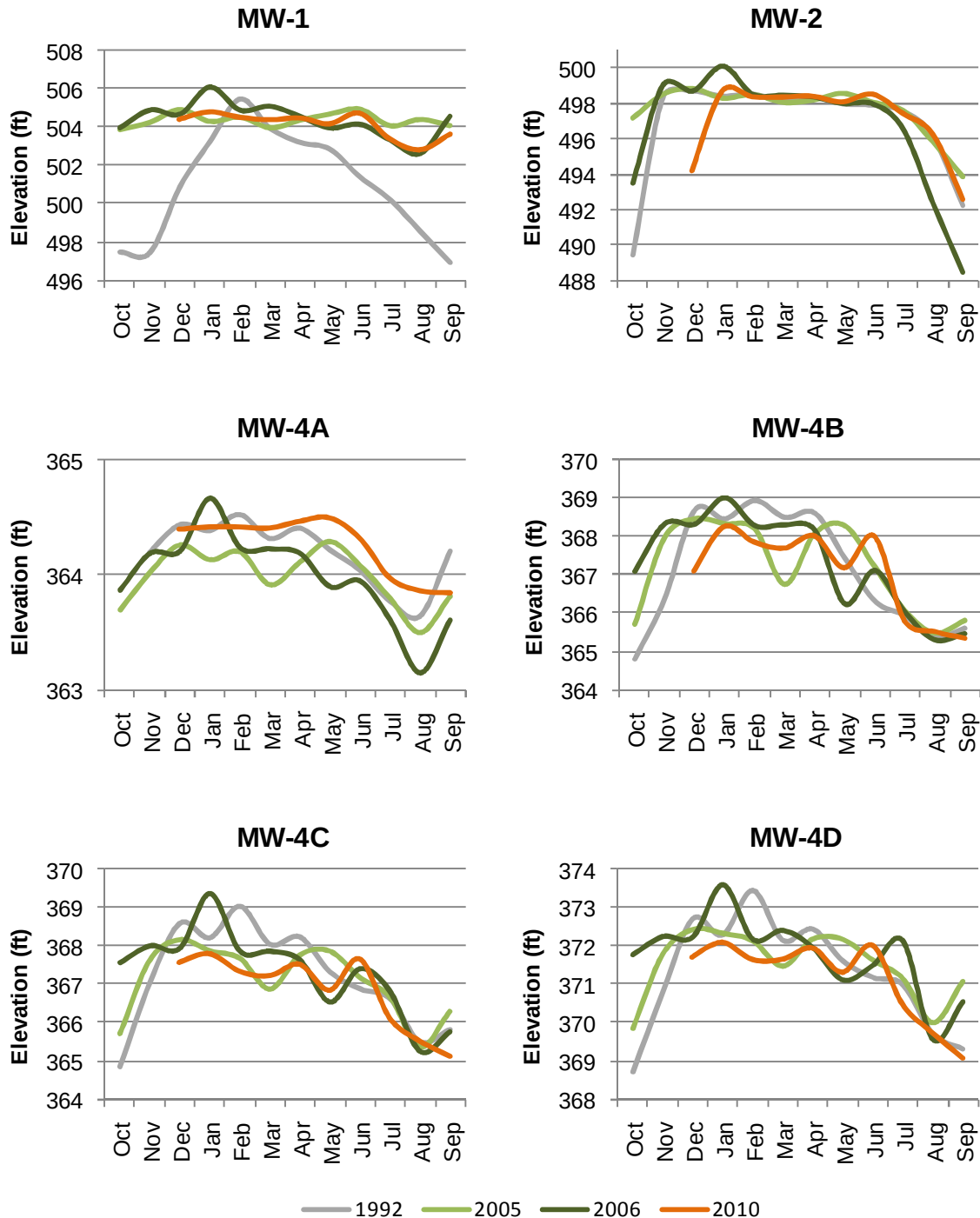


Figure N-1. Trilogy groundwater levels by water year.

Only years with 10 or more months of data were plotted. 1992 (gray) is predevelopment, 2005 and 2006 (greens) are during UPD construction, and 2010 (orange) is post-75% basin buildout for all monitored wells. (Continued next page)

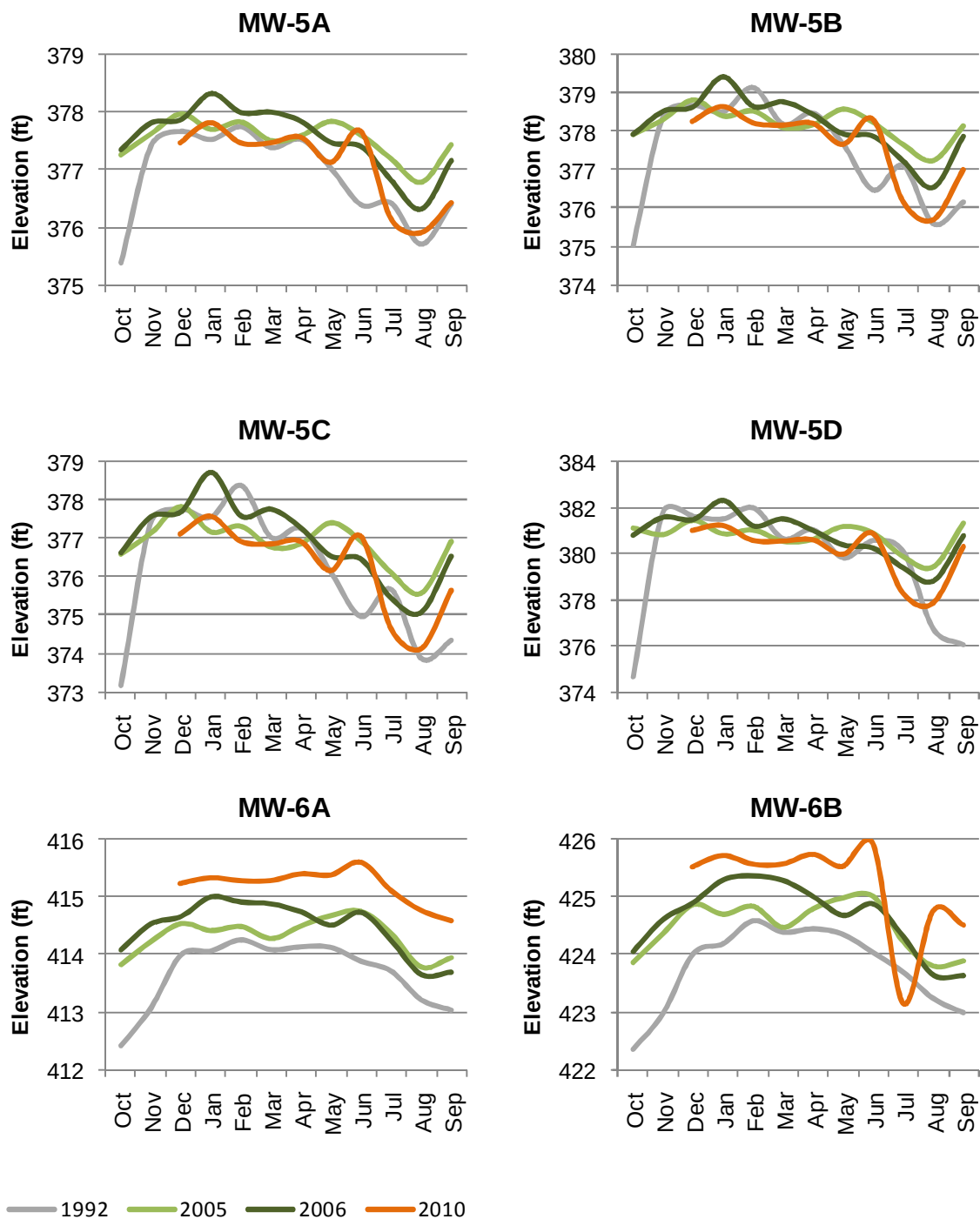


Figure N-1 (Cont'd). Trilogy groundwater levels by water year.
Continued next page.

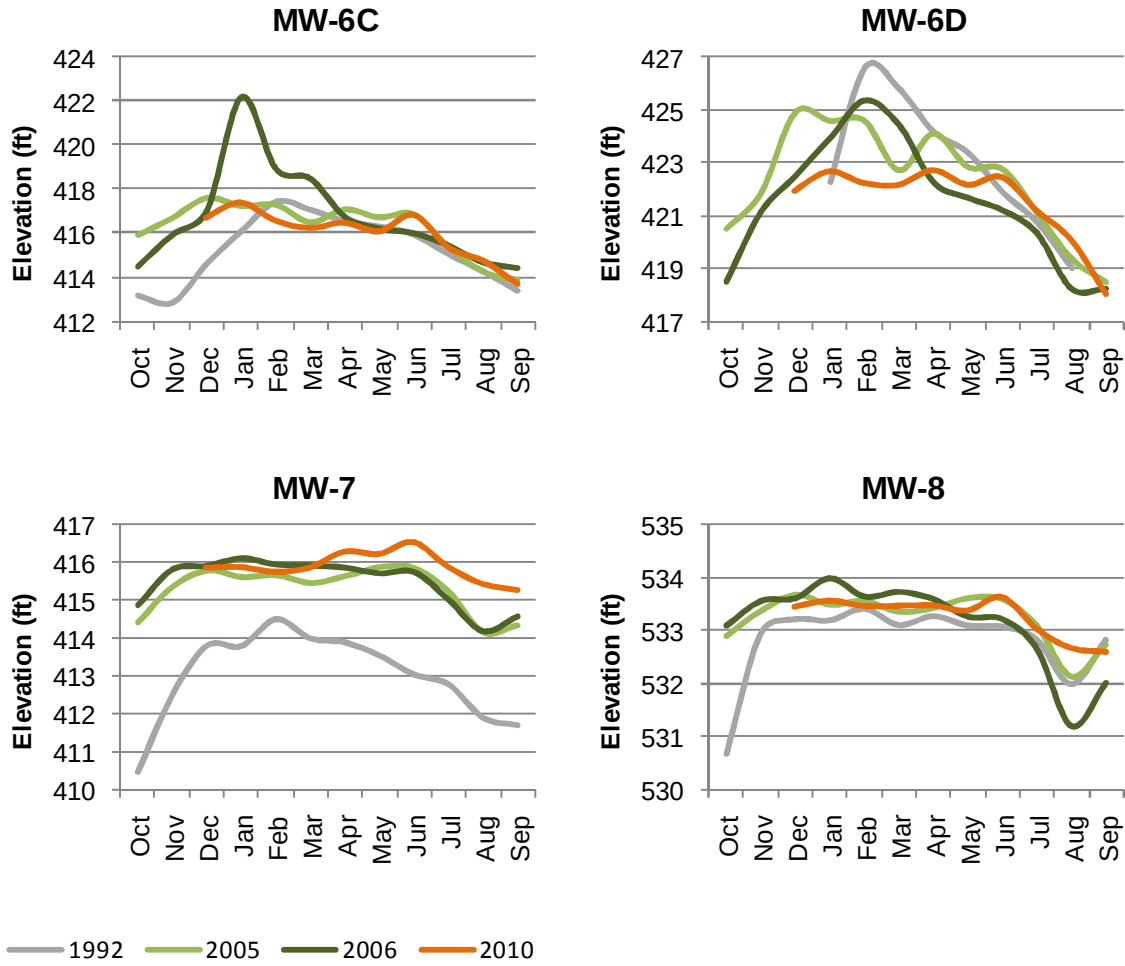


Figure N-1 (Cont'd). Trilogy groundwater levels by water year.

Appendix O. Regional groundwater quality data

Table O-1. Regional groundwater quality data: nitrogen and coliform bacteria.

Data originally pulled together by AESI and A.C. Kindig & Co. for the 2006 Midpoint Review from UPD monitoring in addition to group A and group B well data⁸⁷ (Hugh G. Goldsmith and Associates 2006). Table continued next page.

Sampling Date	System Name	Total NO ₂ +NO ₃ (mg/L)	Nitrate (NO ₃) only (mg/L)	Nitrite (NO ₂) only (mg/L)	Fecals (colonies/ 100 ml)	Total Coliforms (colonies/ 100mL)
3/31/1996	Benedict-Novelty Hill		4.7			
8/1/2002	Chenault	0.55				
12/31/1998	Dawnbreaker (91)		1.5			
12/6/2000	Dawnbreaker (91)		1.4			
12/3/2001	Dawnbreaker (91)	1.1	1.1			
2/9/2003	Dawnbreaker (91)	2.7	2.7			
8/24/2003	Dawnbreaker (91)	1.12	1.12			
11/22/2004	Dawnbreaker (91)	0.97	0.97			
9/14/2005	Dawnbreaker (91)	1.2	1.2			
5/17/2006	Dawnbreaker (91)	1	1			
12/30/2007	Dawnbreaker (91)		<0.2			
12/31/2007	Dawnbreaker (91)	1.2	1.2			
2/9/2003	Dawnbreaker (92)	1	1			
8/24/2003	Dawnbreaker (92)	1.19	1.19			
11/22/2004	Dawnbreaker (92)	0.97	0.97			
9/14/2005	Dawnbreaker (92)	1.3	1.3			
5/17/2006	Dawnbreaker (92)	1.1	1.1			
12/30/2007	Dawnbreaker (92)	1.4	1.4			
12/31/2007	Dawnbreaker (92)	1	1			
9/7/2002	DW-3	-	1.44			<2
9/7/2000	EB-1	0.81				<2
8/8/2002	Fasano	3.6				
4/20/1999	Goldstream		0.2			
11/18/2007	Goldstream	0.5	0.5			
5/13/2001	Hildreth		1			
4/25/2005	Hildreth		1.4			
8/31/1995	IMEL		1.6			
9/12/1999	IMEL		2			
10/31/2002	IMEL		2.3			
11/12/2001	Johnson	1				
7/23/1995	Kaley		2.3			
10/21/1997	Kaley		1.9			
1/19/1999	Kaley	2				
3/9/1999	Kaley	1.4				
9/7/1999	Kaley		2.4			

⁸⁷ Group A and group B public drinking water systems are determined based on the number of service connections and the number of people serviced. Ongoing monitoring of both well types is required by the state Public Health Department to guarantee clean, safe water to well users and includes regular bacteria and nitrate analysis.

Table O-1 (Cont'd). Continued next page.

Sampling Date	System Name	Total NO ₂ +NO ₃ (mg/L)	Nitrate (NO ₃) only (mg/L)	Nitrite (NO ₂) only (mg/L)	Fecals (colonies/ 100 ml)	Total Coliforms (colonies/ 100mL)
5/8/2001	Kaley		1.3			
8/5/2002	Kaley	2.2	2.2			
11/17/2005	Kaley	3.1	3.1			
1/19/1999	Kirkland	1.3				
3/9/1999	Kirkland	0.98				
8/1/2002	Kirkland	1.4				
11/2/1998	Kludt	2.2				
1/19/1999	Kludt	2				
9/18/2001	Kludt	2.1				
8/7/2002	Lane Well B1	0.29				
12/7/1993	McClan		0.1		<1	<1
5/18/1994	McClan		0.2		<1	<1
Oct-91	MW-1		2.72	0.009	<20	
Apr-92	MW-1		4.86	0.007	<20	
Oct-91	MW-2		2	0.119	<20	
Apr-92	MW-2		3.65	0.01	<20	
Oct-91	MW-3		3.02	0.014	<20	
Apr-92	MW-3		7.83	0.015	<20	
Apr-92	MW-4		2.61	0.004	<10	
8/1/2002	Nissley	0.74				
8/3/1999	Oberholtzer (Nov Hill)		<0.50			
2/7/2001	Oberholtzer (Nov Hill)		<0.50			
8/7/2002	Oberholtzer (Nov Hill)	0.56	0.56			
10/23/2006	Oberholtzer (Nov Hill)	0.99	0.99			
1/19/1999	Oberholzer (Shipman)	0.52				
3/9/1999	Oberholzer (Shipman)	<0.5				
8/7/2002	Oberholzer (Shipman)	0.56				
10/13/2010	OBW-11	0.0554			<1	
6/20/2006	OBW-1R	0.57			<2	<2
9/21/2010	OBW-1R	0.267			<1	
6/26/2006	OBW-3R	0.56			<1	<1
10/13/2010	OBW-3R	0.0748			<1	
6/20/2006	OBW-4R	2.6			<1	<1
10/13/2010	OBW-4R	2.07			<1	
2/20/2002	OW-11S	0.65				<2
4/29/2002	OW-11S	0.58				<2
7/16/2002	OW-11S	1.1				<2
1/30/2002	OW-12S	1.9				<18
4/30/2002	OW-12S	1.6				<2
7/16/2002	OW-12S	1.7				<2
10/29/2002	OW-12S	1.1				<1
10/29/2002	OW-9	1				<1
11/10/1999	Ragland-Jones		4			
5/14/2002	Ragland-Jones	2.6	2.6			

Table O-1 (Cont'd). Table concluded.

Sampling Date	System Name	Total NO ₂ +NO ₃ (mg/L)	Nitrate (NO ₃) only (mg/L)	Nitrite (NO ₂) only (mg/L)	Fecals (colonies/ 100 ml)	Total Coliforms (colonies/ 100mL)
10/27/1995	Ridgeview		<0.2			
8/1/2002	Schapelhoaman	0.62				
8/4/2002	Sinconis	0.25				
8/1/1995	Springgay		0.2			
8/25/1998	Springgay		0			
10/31/2005	Springgay		0			
8/8/2002	Stonesifer	5.5				
12/7/1993	Tutko		3.5		<1	<1
5/18/1994	Tutko		0.59		<1	<1
9/18/2001	UHWA (comm. well)	2.6				
12/4/2002	Well G-2 (RRE)	3.9			<2	
1/7/2003	Well G-2 (RRE)	3.2			<1	
2/5/2003	Well G-2 (RRE)	0.11			<1	
3/6/2003	Well G-2 (RRE)	3.6			<1	
4/3/2003	Well G-2 (RRE)	2.3			<1	
11/11/2002	Well OBW-16 (RRE)	2.3			<2	
12/4/2002	Well OBW-16 (RRE)	2.5			2	
1/7/2003	Well OBW-16 (RRE)	2.6			<1	
2/5/2003	Well OBW-16 (RRE)	0.14			<1	
3/6/2003	Well OBW-16 (RRE)	2.4			<1	
4/3/2003	Well OBW-16 (RRE)	1.6			<1	

Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Stream and Wetland Hydrologic Monitoring Assessment

Prepared by: Curtis DeGasperi. King County Department of Natural Resources and Parks,
Water and Land Resources Division. April 2011.



King County

Department of
Natural Resources and Parks

Water and Land Resources Division

201 South Jackson Street, Suite 600
Seattle, WA 98104

Table of Contents

1.0	Introduction	1
2.0	Stream Hydrology	6
2.1	Evaluation Methods.....	6
2.2	Results.....	7
2.3	Summary	15
2.4	Corrective Actions.....	15
3.0	Wetland Hydrology	16
3.1	Evaluation Methods.....	16
3.2	Results.....	18
3.3	Summary	31
3.4	Corrective Actions.....	32
4.0	References.....	33
5.0	Appendices.....	35
	Appendix A. Peak flows.....	37
	Appendix B. Flow flashiness	51
	Appendix C. Base flow	58
	Appendix D. Wetland Water Levels	65
	Appendix E. Wetland June 30, spring/summer median and winter median water levels	71
	Appendix F. Wetland Water Level Fluctuations	83

Tables

Table 1.	Trilogy and Redmond Ridge stream hydrology monitoring locations	6
Table 2.	Trilogy and Redmond Ridge wetland hydrology monitoring locations	16

Figures

Figure 1.	Location map of stream and wetland hydrologic monitoring locations in the Trilogy and Redmond Ridge Urban Planned Developments.....	2
Figure 2.	Comparison of modeled pre-development daily maximum discharge to observed daily maximum discharge from the NE Trilogy basin HSPF model representing the Adair Creek Station 53A.....	4

Figure 3. Comparison of modeled post-development daily maximum discharge to observed daily maximum discharge from the NE Trilogy basin HSPF model representing the Adair Creek Station 53A.....	5
Figure 4. Daily maximum discharge observed at the Adair Creek (53A) gage.	8
Figure 5. Annual maximum discharge observed at the Colin Creek North (02C) gage.	9
Figure 6. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Adair Creek (53A) gage.	11
Figure 7. Number of days each summer (July-October) that Wallace Creek West (53B) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.....	13
Figure 8. Number of days each summer (July-October) that Rutherford Creek (18F) was dry (daily mean flow = 0.00) and the number of days over the same period that daily mean flow was less than 0.1 cfs.	14
Figure 9. Observations of wetland water levels in Redmond Ridge wetland BBC-52.....	19
Figure 10. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland BBC-52.	20
Figure 11. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-52.	21
Figure 12. Observations of wetland water levels in Redmond Ridge wetland BBC-45.....	22
Figure 13. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-45.	23
Figure 14. Observations of wetland water levels in Redmond Ridge wetland EC-3.....	24
Figure 15. Observations of wetland water levels in Redmond Ridge wetland EC-61.....	25
Figure 16. Observations of wetland water levels in Redmond Ridge wetland EC-4.....	26
Figure 17. Observations of wetland water levels in Redmond Ridge wetland BBC-UN1.	27
Figure 18. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-UN1.	28
Figure 19. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetlands BBC-45A, BBC-26, SR-24A and SR-24C.	29
Figure 20. Observations of wetland water levels in Trilogy wetland BBC-26.	30
Figure 21. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetlands BBC-44 and SR-24B.	31
Figure A-1. Daily maximum discharge observed at the Adair Creek (53A) gage.	37
Figure A-2. Annual maximum discharge observed at the Adair Creek (53A) gage.....	38
Figure A-3. Daily maximum discharge observed at the Wallace Creek West (53B) gage.....	39
Figure A-4. Annual maximum discharge observed at the Wallace Creek West (53B) gage.....	40
Figure A-5. Daily maximum discharge observed at the Wallace Creek North (53C) gage.....	41
Figure A-6. Annual maximum discharge observed at the Wallace Creek North (53C) gage.....	42
Figure A-7. Daily maximum discharge observed at the Colin Creek North (02C) gage.....	43

Figure A-8. Annual maximum discharge observed at the Colin Creek North (02C) gage.	44
Figure A-9. Daily maximum discharge observed at the Colin Creek South (02D) gage.....	45
FigureA-10. Daily maximum discharge observed at the Colin Creek South (02D) gage.....	46
Figure A-11. Daily maximum discharge observed at the Rutherford Creek (18F) gage.....	47
Figure A-12. Daily maximum discharge observed at the Rutherford Creek (18F) gage.....	48
Figure A-13. Daily maximum discharge observed at the Evans Creek Central South (18B) gage.....	49
Figure A-14. Daily maximum discharge observed at the Rutherford Evans Creek Central South (18B) gage.....	50
Figure B-1. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Adair Creek (53A) gage.....	51
Figure B-2. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Wallace Creek West (53B) gage.....	52
Figure B-3. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Wallace Creek North (53C) gage.....	53
Figure B-4. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Colin Creek North (02C) gage. ...	54
Figure B-5. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Colin Creek South (02D) gage. ...	55
Figure B-6. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Rutherford Creek (18F) gage.....	56
Figure B-7. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Evans Creek Central South (18B) gage.....	57
Figure C-1. Number of days each summer (July-October) that Adair Creek (53A) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.	58
Figure C-2. Number of days each summer (July-October) that Wallace Creek West (53B) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.	59
Figure C-3. Number of days each summer (July-October) that Wallace Creek North (53F) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.	60
Figure C-4. Number of days each summer (July-October) that Colin Creek North (02C) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.....	61
Figure C-5. Number of days each summer (July-October) that Colin Creek South (02D) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.....	62

Figure C-6. Number of days each summer (July-October) that Rutherford Creek (18F) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.....	63
Figure C-7. Number of days each summer (July-October) that Evans Creek Central South (18B) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.	64
Figure D-1. Observations of wetland water levels in Trilogy wetland BBC-44.	65
Figure D-2. Observations of wetland water levels in Trilogy wetland BBC-45A.	66
Figure D-3. Observations of wetland water levels in Trilogy wetland BBC-26.	67
Figure D-4. Observations of wetland water levels in Trilogy wetland SR-24A.	68
Figure D-5. Observations of wetland water levels in Trilogy wetland SR-24B.....	69
Figure D-6. Observations of wetland water levels in Trilogy wetland SR-24C.....	70
Figure E-1. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland BBC-44.....	71
Figure E-2. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland BBC-45A.	72
Figure E-3. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland BBC-26.....	73
Figure E-4. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland SR-24A.....	74
Figure E-5. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland SR-24B.	75
Figure E-6. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland SR-24C.	76
Figure E-7. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland EC-3.....	77
Figure E-8. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland EC-61.....	78
Figure E-9. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland EC-4.....	79
Figure E-10. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland BBC-52.	80
Figure E-11. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland BBC-45.	81
Figure E-12. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland BBC-UN1.	82
Figure F-1. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetland BBC-44.....	83
Figure F-2. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetland BBC-45A.	83

Figure F-3. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetland BBC-26.....	84
Figure F-5. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetland SR-24B.	85
Figure F-6. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetland SR-24C.	85
Figure F-7. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland EC-3.....	86
Figure F-8. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland EC-61.....	86
Figure F-9. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland EC-4.....	87
Figure F-10. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-52.....	87
Figure F-11. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-45.....	88
Figure F-12. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-UN1.	88

1.0 INTRODUCTION

Trilogy (formerly Blakely Ridge) and Redmond Ridge (formerly Northridge) are adjoining Urban Planned Developments (UPDs) located on approximately 2,560 acres (1,035 hectares) in north central unincorporated King County, Washington. This report presents the results from stream and wetland hydrologic monitoring conducted with the intent of ensuring that the UPDs did not significantly disrupt the pre-development hydrology. The hydrologic monitoring methods followed recommendations specified in the original Redmond Ridge and Trilogy post-development monitoring plans and are described in more detail in King County (2010). The stream and wetland hydrologic monitoring locations evaluated in this report are shown in Figure 1.

The overall goal of the hydrologic monitoring was to determine if there were unexpected changes in the hydrology of streams and wetlands as a result of UPD construction and full build out. A complex system of storm water controls was built into the developments to maintain the hydrologic response of the streams and wetlands near their predevelopment condition. The post-development monitoring was intended to assess the hydrologic response of streams and wetlands compared to their pre-development condition. Standard engineering practice relies on hydrologic simulation models to evaluate the effects of planned development on stream and wetland hydrology and to evaluate the ability of various measures, including storm water detention facilities, to mitigate the impacts of development on hydrology.

Performance criteria were established in the drainage plans (Hugh G. Goldsmith & Associates 1996; Northwest Engineering Company 1995) that were used to site and size storm water control facilities to:

- Minimize the potential impacts on wetland water levels to protect wetland flora and fauna,
- Maintain peak flood flows at pre-development levels so as not to impact downstream conveyance or increase downstream flooding, and
- Maintain developed condition flow durations below the pre-development flow durations between one-half of the pre-development 2-year peak flow to the 100-year return flow to prevent destabilization of the geomorphic balance of the stream system downstream of the development.

These performance criteria were developed in the drainage plans and were intended for use in continuous simulation models (Hydrological Simulation Program–Fortran or HSPF)¹ that were calibrated to stream flow and wetland level measurements made before development was initiated. The calibrated models were then used to represent fully developed conditions, including storm water control facilities that were then sized through an iterative modeling process comparing developed to pre-developed condition model output until the performance criteria outlined above were met.

¹ HSPF is a continuous simulation hydrologic model supported by the U.S. Geological Survey and the Environmental Protection Agency (Bicknell *et al.* 2005)

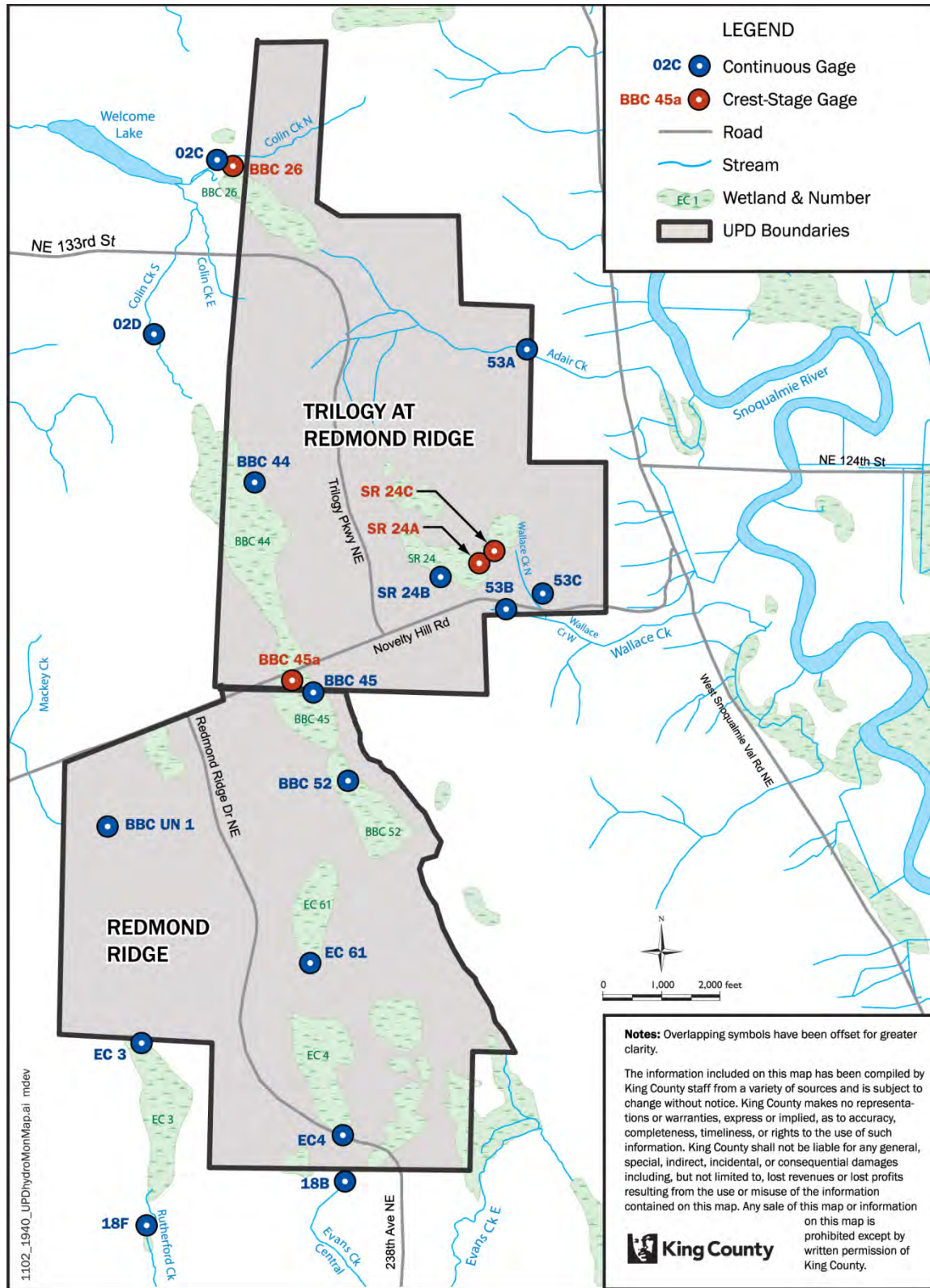


Figure 1. Location map of stream and wetland hydrologic monitoring locations in the Trilogy and Redmond Ridge Urban Planned Developments.

In the 2007 Trilogy and Redmond Ridge UPD monitoring report (King County 2010), the modeling performance criteria found in Otak, Inc. (2007) were used to evaluate stream flow and wetland level monitoring data with respect to potential unmitigated impacts of development. These performance goals described in the HSPF modeling report for Trilogy (Otak, Inc. 2007) are summarized below:

Wetland Hydrology

- Post-development 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.
- Post-development winter (November-March) median water levels will change by no more than 0.5 feet over pre-developed levels.
- 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.
- Post-development spring/summer (April-October) median water levels will change by no more than 0.25 feet over predevelopment levels.
- Post-development spring/summer (April-October) water level duration curves match predevelopment curves to within a maximum of 0.5 feet at all durations.

Stream Hydrology

- Post-development peak flows and flow durations will be equal to or less than pre-development peak flows and durations for all discharges above one-half of the pre-development two-year return flows.

However, these are not the Threshold Exceedance Criteria for the stream and wetland hydrology monitoring elements established in the Post-Development Monitoring Plan for the Trilogy UPD (King County 2001). The Threshold Exceedance Criteria found in the Trilogy UPD monitoring plan are as follows:

Wetland Hydrology

- Deviations from modeled and predicted water level fluctuations of greater than 20 percent or hydrologic deviations correlated with declines in amphibian communities that have shown two consecutive years of impacts.

Stream Hydrology

- Changes in base flow, peaks, and/or durations deviate by 20 percent or more from DMP predicted and modeled discharges.
- Changes greater than 20 percent in duration of drying period as compared to baseline flow records.
- Bypass flows occurring during flow plus or minus 20 percent of the drainage plan settings.

Very similar Exceedance Criteria were established for the Redmond Ridge UPD (King County 1999).

While setting exceedance criteria based on modeled pre-development hydrologic conditions seems intuitively reasonable, this assumes that the modeled pre-development flows are accurate enough for quantitative comparison to observed data. Although the HSPF models were calibrated to pre-development data, and the calibration was approved by the King County Surface Water Management Division, the period of record used was relatively short (for the Trilogy UPD generally less than 2 years of data) and the calibration focused on qualitatively matching peak flows and quantitatively evaluating model fit to annual and seasonal flow volumes. Model fit of the Trilogy HSPF models based on quantitative criteria² ranged from good (10-15% difference) to fair (15-25% difference).

To best illustrate the ability of the HSPF models to predict observed flows, the model precipitation input to the Northeast (NE) Trilogy HSPF model was extended through September 2010 and run for pre- and post-development conditions starting in October 1989 as in the original model calibration. The comparison of modeled pre-development and observed (gaged) daily maximum discharge for the pre-development gauging period of April 1990 to June 1994 is shown in Figure 2.

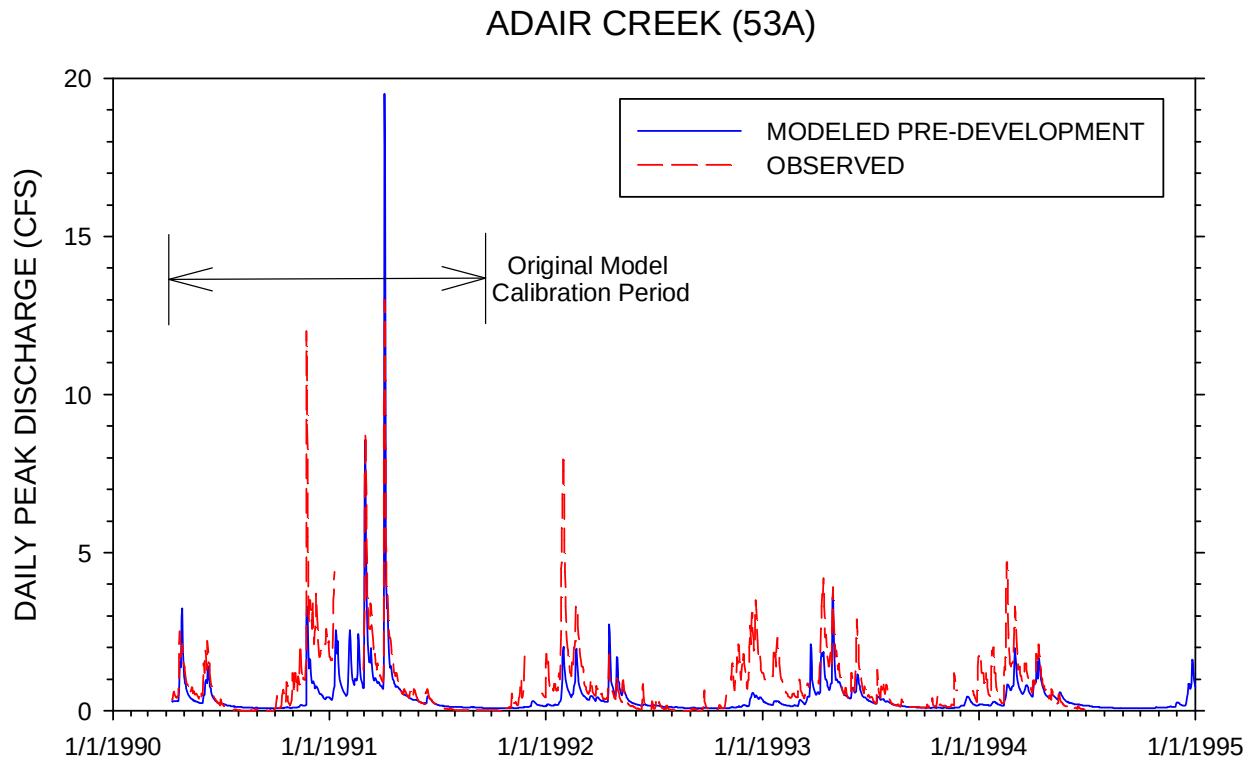


Figure 2. Comparison of modeled pre-development daily maximum discharge to observed daily maximum discharge from the NE Trilogy basin HSPF model representing the Adair Creek Station 53A.

² Model calibration criterion was percent difference: $[(\text{Simulated} - \text{Observed}) / (\text{Observed})] \times 100$

Qualitatively, it appears that the model typically under-predicted observed peak flows, with one clear exception which was the peak flow observed on April 5, 1991 of 13 cfs – the model predicted a maximum discharge of 16.9 cfs on that day and a maximum of 19.5 cfs for the pre-development modeling period on April 4, 1991. Note that the original model calibration used only data collected through September 1991.

As a further indication of the reliability of the models as benchmarks for evaluating the monitoring data, the modeled post-development daily maximum discharge is compared to observed daily maximum discharge after 75 percent buildout of the NE Trilogy basin was reached (i.e., September 2007) (Figure 3).

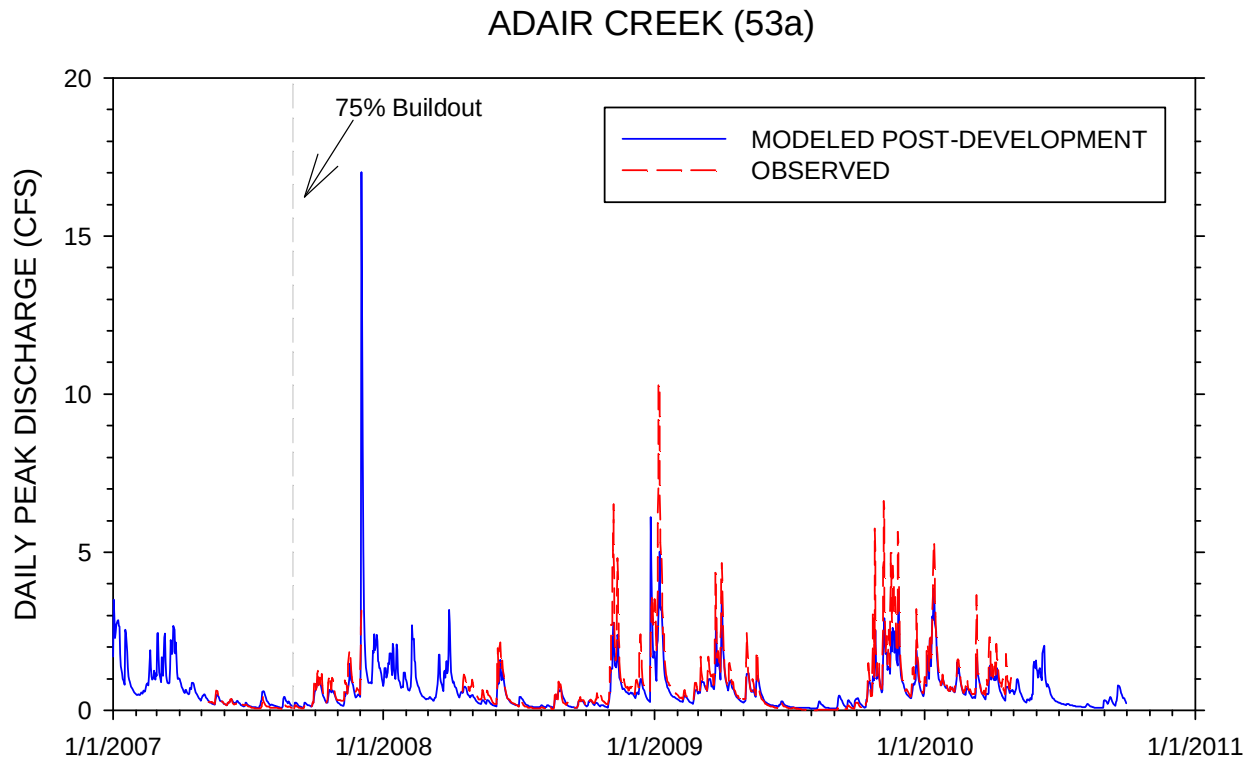


Figure 3. Comparison of modeled post-development daily maximum discharge to observed daily maximum discharge from the NE Trilogy basin HSPF model representing the Adair Creek Station 53A.

Again it appears that the model generally under-predicted daily peak flows, although observed data are missing for the water year 2008 winter period in which the model predicted the maximum discharge event of the post-development period (17.0 cfs on December 3, 2007). In general, these comparisons are not intended to imply that the models were inadequately calibrated for their intended use in designing the storm water control facilities – in fact storm water facility design is more typically conducted without the additional step of calibration to continuous discharge data. Nonetheless, while the HSPF models used to design the storm water control facilities followed the engineering standards set by King County and the UPD drainage plans; this does not necessarily mean that the models would be appropriate for setting quantitative post-construction monitoring benchmarks (i.e., Threshold Exceedance Criteria or Exceedance Criteria).

Although it may be possible to recalibrate the pre-development models to set benchmarks for post-development data in a “synthetic paired basin approach” (*sensu* Hartley and Funke 2001), such an effort is beyond the scope of this evaluation. The remainder of this report describes an alternative data-based approach to evaluating potential impacts of the UPDs on stream and wetland hydrology. The evaluation of stream hydrology is presented first, followed by an analysis of wetland hydrology.

2.0 STREAM HYDROLOGY

The seven stream monitoring locations evaluated in this report are shown in Figure 1 and are listed and described in Table 1. For a more detailed description of the methods used and issues encountered during the monitoring program, the reader is referred to King County (2010).

Table 1. Trilogy and Redmond Ridge stream hydrology monitoring locations

	Pre-Development	Post-Construction
Trilogy		
Southwest Drainage (Colin South)		
Colin Creek South (02D)		Continuous Stage/Discharge
Northwest Drainage (Colin North)		
Colin Creek North (02C)		Continuous Stage/Discharge
Northeast Drainage (Adair)		
Adair Creek (53A)		Continuous Stage/Discharge
Southeast Drainage (Wallace)		
Wallace Creek North (53C)		Continuous Stage/Discharge
Wallace Creek West (53B)		Continuous Stage/Discharge
Redmond Ridge		
Evans Creek West (Rutherford)		
Rutherford Creek (18F)	No Data	Continuous Stage/Disch.
Evans Creek Central		
Evans Creek Central (18B)		Continuous Stage/Discharge

2.1 Evaluation Methods

In place of comparisons to model output to determine if there were unexpected changes in the hydrology of the UPD streams as a result of UPD construction and development, the following metrics were calculated and trends over time were assessed by plotting each metric vs. time.

- Peak flow: Annual maximum instantaneous peak discharge.

- Flow Flashiness: Hydrologic indicators of flow flashiness - TQmean, High Pulse Count, and Richards-Baker Index (R-B Index)³.
- Base Flow: Number of days daily mean discharge was recorded as 0.00 cfs and the number of days daily mean discharge was recorded as less than 0.1 cfs based on gage recordings between July and October of each year.

In years in which data were missing over the period of interest for a particular metric, the metric was omitted from the time series plot.

Ideally, trends would be assessed objectively by using the non-parametric Mann-Kendall trend test (Helsel and Hirsch 2002). The Mann-Kendall test is widely used for testing trends in hydrologic data that are not normally distributed (a requirement for parametric trend tests) and contain missing values. However, due to the multi-year data gap in the mid- to late 1990s and the number of additional years with missing data, quantitative trend testing was deemed infeasible. Therefore, potential trends were identified through visual inspection of time series plots of each metric for each gage record.

2.2 Results

Peak Flow

To identify years in which annual peak flow could be reliably evaluated, the daily maximum flow at each gage was plotted – for an example see Figure 4. In years in which it appeared that peak flows were missed due to data gaps during the peak flow period (Nov-Mar) based on review of associated daily rainfall data, or there were no data for that period, an annual peak flow value was not plotted. In general, there were no apparent visual trends in the peak flow data time series, although there was an apparent increase in annual peak flow at Colin Creek North (02C) after construction was initiated. However, the highest peak observed post-buildout was associated with a significant amount of winter precipitation and the last peak observed (winter of 2009-2010) at the Colin Creek North gage (02C) was within the range of pre-development peak flows (Figure)

Figures illustrating daily maximum and annual peak flows for the seven monitored streams are provided in Appendix A.

³ TQmean is the fraction of time daily average flow is greater than the annual mean flow, High Pulse Count is the number of times each year that the daily flow is greater than twice the long term mean flow, and the R-B Index is the annual sum of absolute differences in consecutive daily discharge values divided by the sum of annual daily flow values.

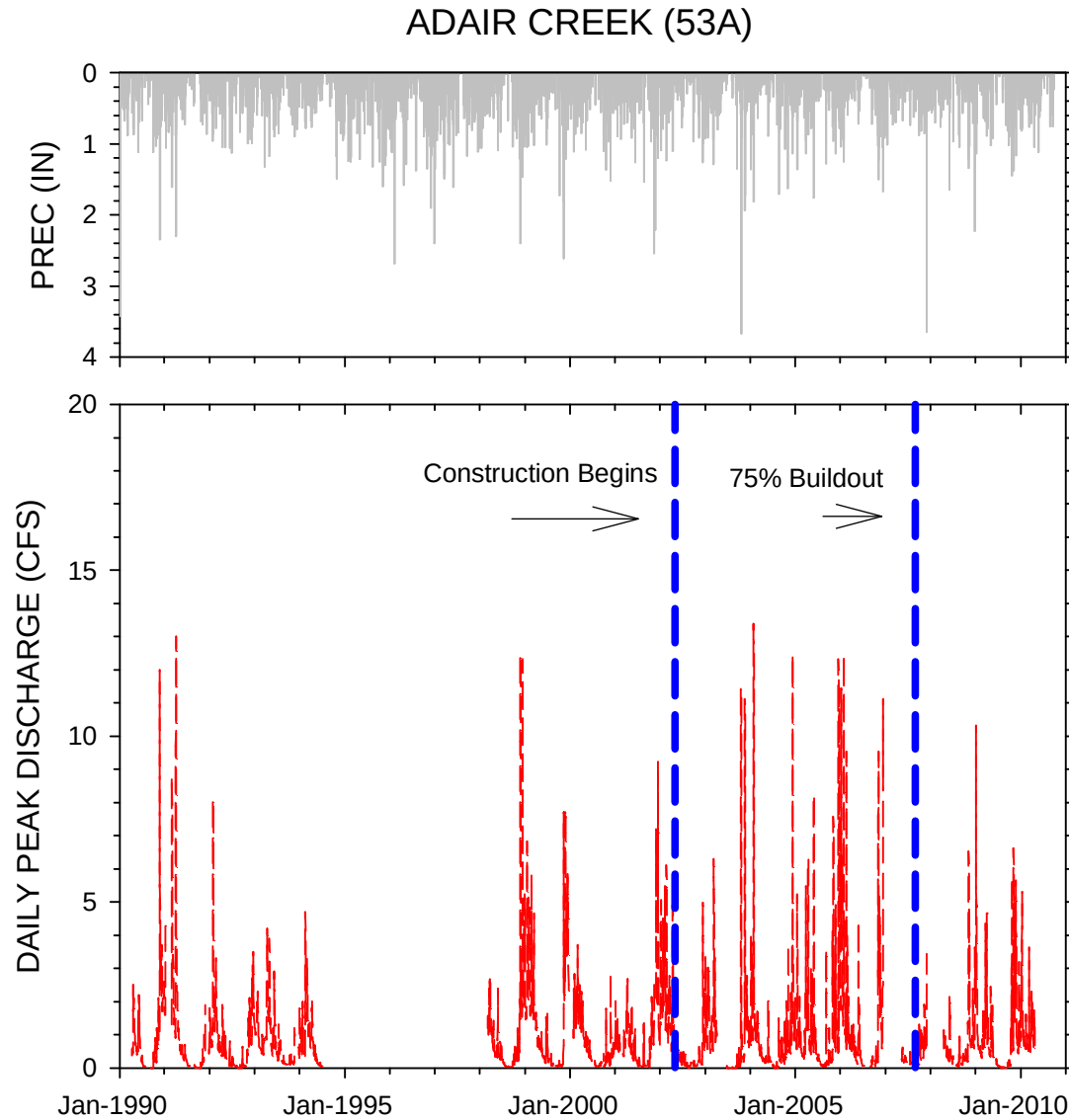


Figure 4. Daily maximum discharge observed at the Adair Creek (53A) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NE basin.

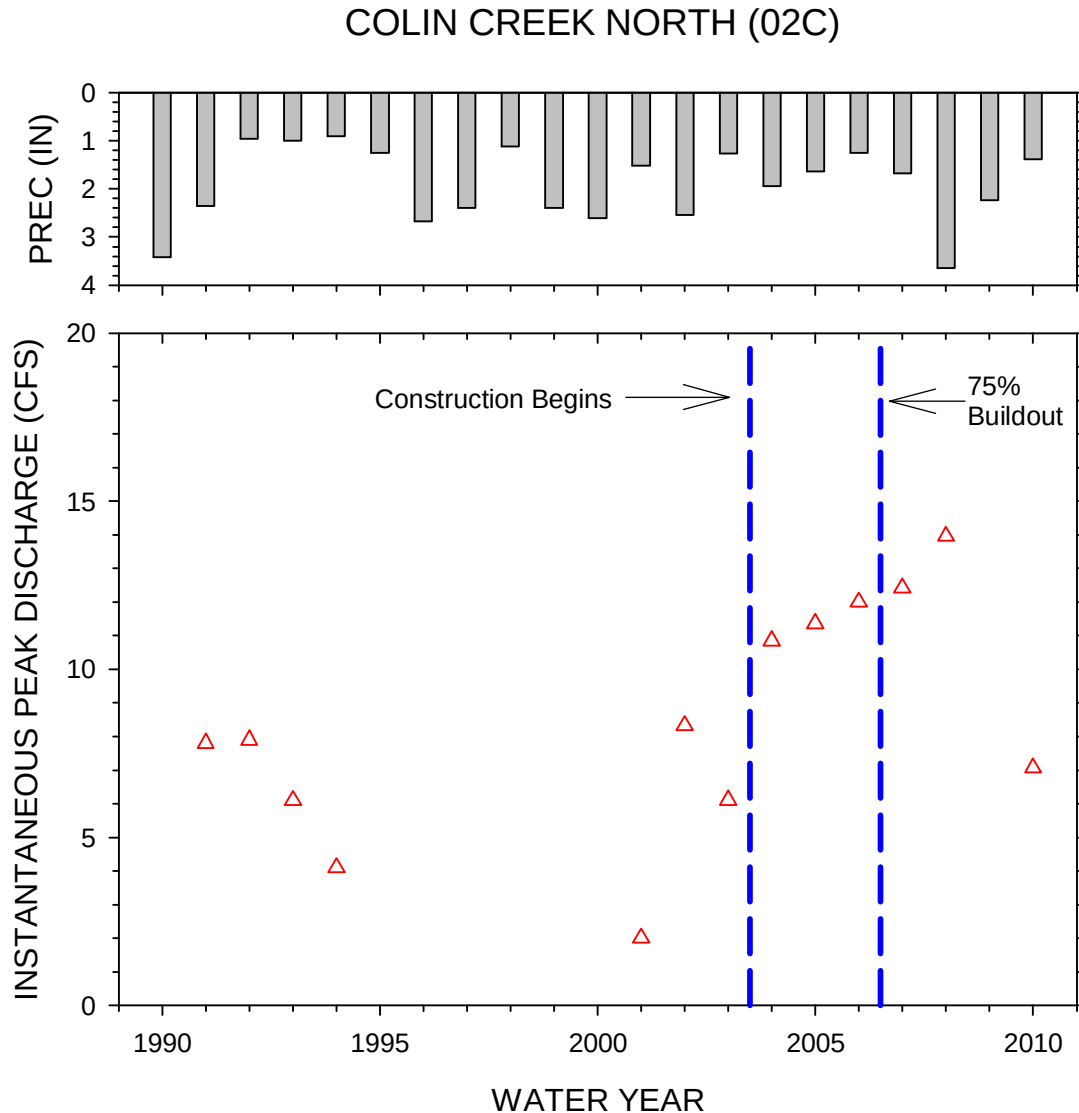


Figure 5. Annual maximum discharge observed at the Colin Creek North (02C) gage.

Top panel shows maximum daily precipitation observed during the period Nov-Feb. Data were insufficient during the winter (Nov-Feb) of 2009 to estimate peak flow. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NW basin.

Flow Flashiness

Although flow flashiness was not a metric that was included in the suite of Threshold Exceedance Criteria in the original monitoring plan, research since the plan was developed has suggested that hydrologic metrics representing flow flashiness have a potential to be ecologically relevant (Booth *et al.* 2004, DeGasperi *et al.* 2009). Of the three metrics evaluated here, High Pulse Count was used to evaluate the potential impact of development on Adair Creek (53A) in the midpoint review (King County, 2006). TQmean was used by Booth *et al.* (2004) and DeGasperi *et al.* (2009) to illustrate the potential biological relevance of particular hydrologic metrics. The R-B Index has been shown to be potentially biologically relevant and to have

relatively low inter-annual variability, which makes it a potentially more sensitive metric for detecting hydrologic changes resulting from development (DeGasperi *et al.* 2009).

To calculate these metrics, the daily mean flow data were screened for missing values and only years in which there were no missing data were plotted. In general, there were no apparent trends with the possible exception of TQmean and R-B Index calculated for Adair Creek (53A) which appeared to shift⁴, indicating more flashiness, after construction began (Figure 6). However, High Pulse Count in Adair Creek did not appear to change before and after construction was initiated.

Figures illustrating trends in flashiness metrics at the seven monitored streams are provided in Appendix B.

⁴ An increase in R-B Index or High Pulse Count, or a decrease in TQmean, over time would indicate an increase in stream flashiness.

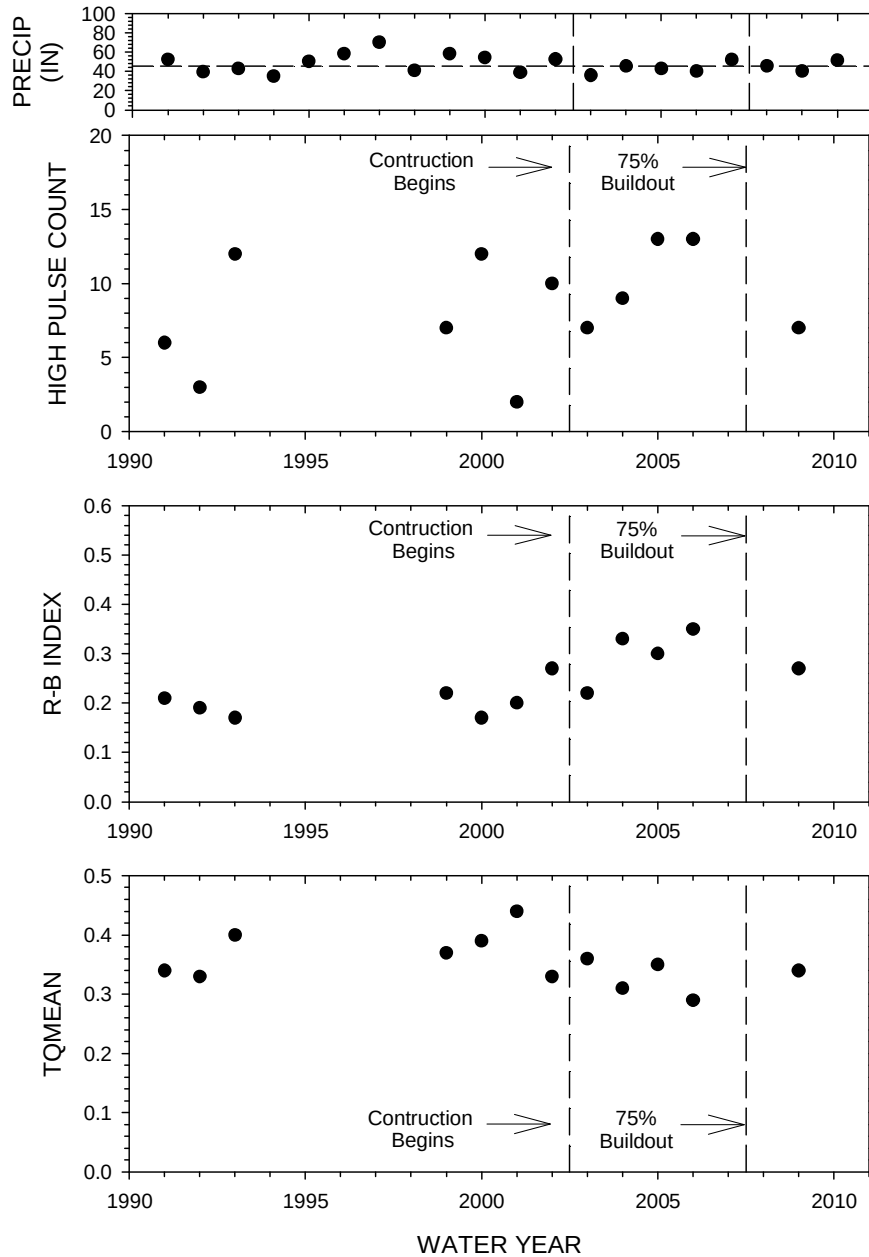


Figure 6. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Adair Creek (53A) gage.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NE basin. Metrics were not calculated for years in which any daily average data were missing. Therefore, no flashiness metrics are plotted in the graphs above for 2007, 2008, or 2010.

Base Flow

To evaluate potential trends in changes in stream baseflow, two “drying” metrics were used. One was the number of days during the summer low flow period of July through October that a flow of zero was recorded. The second was the number of days that a flow of less than 0.1 cfs

was recorded during the same period. Summers in which there were more than 1 missing day of recorded flows were excluded from the analysis.

In general, it does not appear that the gaged streams have become drier. In fact, two streams appear to have slightly higher low flows than those observed prior to development based on trends in the number of days that flow is less than 0.1 cfs. Summer flows less than 0.1 cfs were observed approximately 100 days between July and October at the Wallace Creek West (53B) gage prior to development, but have been observed on only 2 days in 2008 and zero days in 2010 (Figure 7). Although Rutherford Creek (18F) does not typically go dry during the summer, post-development summer flows were less frequently below 0.1 cfs than flows measured during the construction phase (Figure 8).

Figures illustrating trends in stream drying at the seven monitored streams are provided in Appendix C.

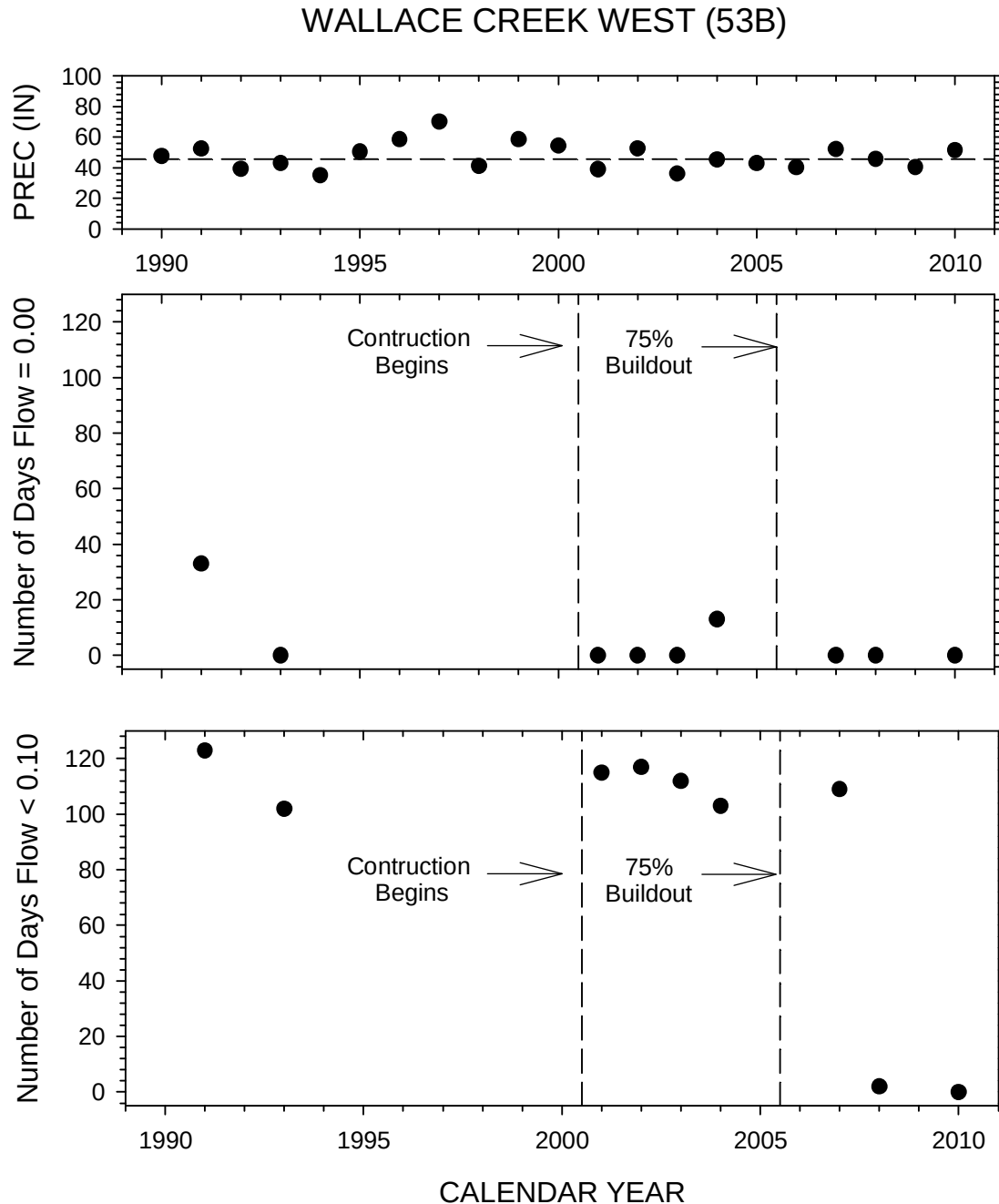


Figure 7. Number of days each summer (July-October) that Wallace Creek West (53B) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage. Metrics were not calculated for years in which any daily average summer flow data were missing. Therefore, no metrics are plotted in the graphs above for 1992, 2005, 2006, or 2009.

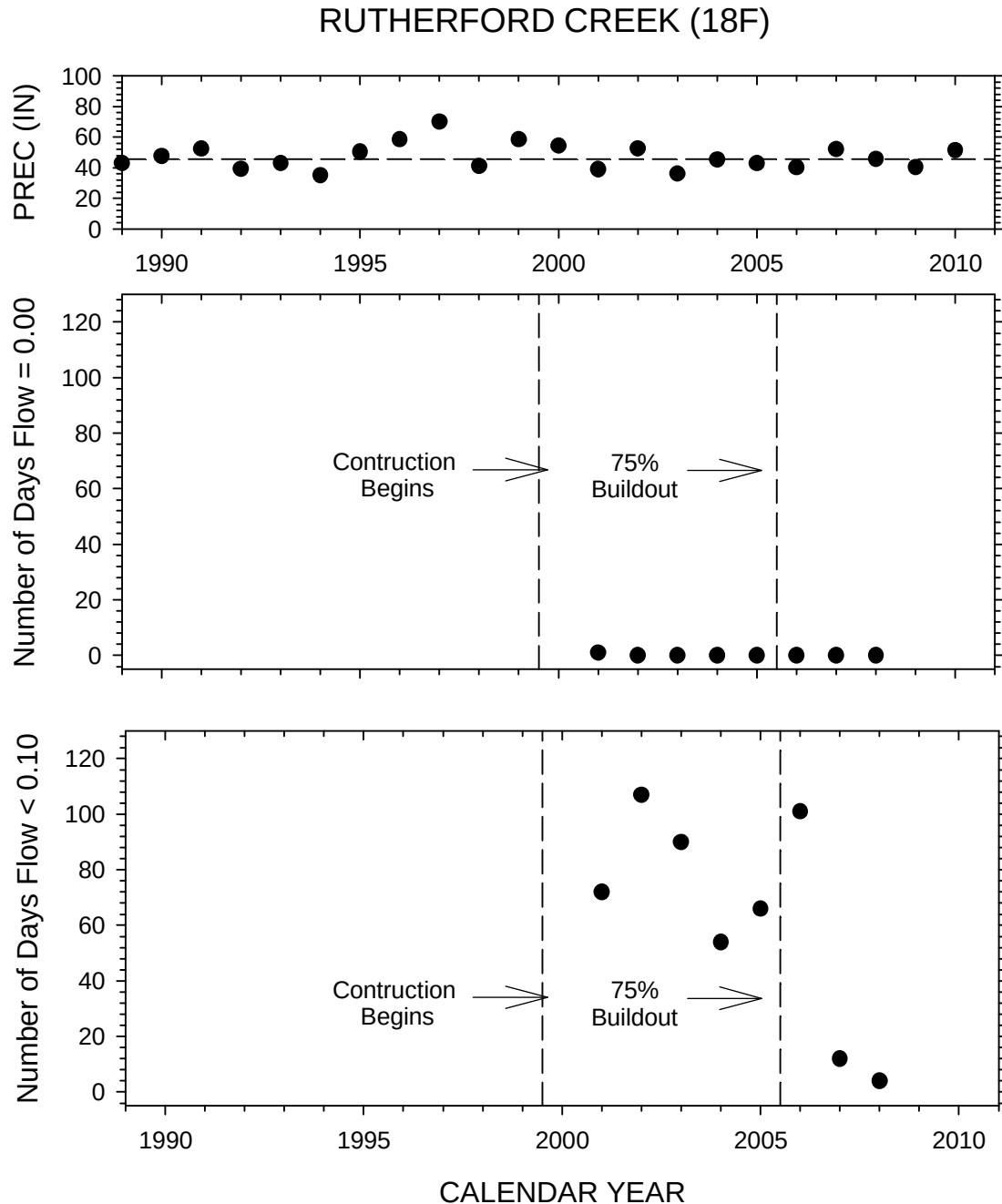


Figure 8. Number of days each summer (July-October) that Rutherford Creek (18F) was dry (daily mean flow = 0.00) and the number of days over the same period that daily mean flow was less than 0.1 cfs. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage. Metrics were not calculated for years in which any daily average summer flow data were missing. Therefore, no metrics are plotted in the graphs above for 2009 or 2010.

2.3 Summary

Peak Flow

Although there was a potential trend in annual peak flow at Colin Creek North (02C), the highest peak observed post-buildout was associated with a significant amount of winter precipitation and the last peak observed (winter of 2009-2010) at the Colin Creek North gage (02C) was within the range of pre-development peak flows.

Overall, it appears that the construction and development within the UPD has not significantly affected peak flows.

Flow Flashiness

Flow flashiness metrics for Colin Creek North did not appear to suggest any trends. Flow flashiness metrics, R-B Index and TQmean, suggested a trend toward more flow flashiness at Adair Creek gage 53A, although similar to the Colin Creek North gage there was only one reliable post 75% buildout record for comparison. The shift toward flashier stream flow in Adair Creek appears to have happened at the point that construction was initiated.

Based on the available data, it appears that the construction and development within the UPD has not resulted in flashier flows with the possible exception of Adair Creek. The apparent shift does not appear to be associated with effects on channel erosion or stream biota (King County 2011).

Base Flow

Based on the available data, it appears that the construction and development within the UPD has not resulted in more frequent periods of dry streams or longer periods of extreme low flow. On the contrary, the available data suggest that streams may be drier less often and periods of extreme low flow are shorter. This is not unexpected considering that the source of potable water comes from outside of the basin. Although much of the imported water is likely exported to the regional wastewater conveyance system, potable water supply leakage and application of excess irrigation water in the summer have a potential to measurably increase summer baseflow.

2.4 Corrective Actions

Concern for maintaining pre-development peak flows is primarily driven by a desire to prevent erosion of the stream channel and prevent unexpected flooding. Concern for flow flashiness is primarily driven by a desire to prevent degradation of stream biological communities. It does not appear that significant changes have occurred in the gaged stream channel cross sections or that shifts have occurred in the stream biological communities sampled in the vicinity of these gages that are consistent with the trends suggested in Colin Creek North or Adair Creek (King County 2011). No corrective actions are recommended for the stream hydrology component of the monitoring plan.

3.0 WETLAND HYDROLOGY

The twelve wetland monitoring locations evaluated in this report are shown in Figure 1 and are listed and described in Table 2. For a more detailed description of the methods used and issues encountered during the monitoring program, the reader is referred to King County (2010).

Table 2. Trilogy and Redmond Ridge wetland hydrology monitoring locations

	Pre-Development	Post-Construction
Trilogy		
Southwest Drainage (Colin South)		
BBC-44	No Data	Continuous Stage
BBC-45A	Staff Plate/Crest-Stage	Staff Plate/Crest-Stage
Northwest Drainage (Colin North)		
BBC-26	Staff Plate/Crest-Stage	Staff Plate/Crest-Stage
Southeast Drainage (Wallace)		
SR-24A	Staff Plate/Crest-Stage	Staff Plate/Crest-Stage
SR-24B	No Data	Continuous Stage
SR-24C	Staff Plate/Crest-Stage	Staff Plate/Crest-Stage
Redmond Ridge		
Evans Creek West (Rutherford)		
EC-3	Staff Plate	Continuous Stage
Evans Creek Central		
EC-61	Staff Plate	Continuous Stage
EC-4	Staff Plate	Continuous Stage
Big Bear Creek		
BBC-52	Staff Plate	Continuous Stage
BBC-45	Staff Plate	Continuous Stage
Mackey Creek		
BBC-UN1	Staff Plate	Continuous Stage

3.1 Evaluation Methods

As noted above with respect to using HSPF models to establish exceedance criteria for comparison to observed stream flows, the HSPF models even when calibrated are generally not accurate enough to establish absolute water level targets for wetland levels. For example, Azous *et al.* (2001) indicate that the typical accuracy of HSPF wetland level modeling is on the order of ± 15 cm (0.5 ft). This level of accuracy is greater than or equal to most of the wetland modeling targets used in the original design of stormwater facilities in the UPDs (see Introduction). This does not mean to imply that the original modeling targets were unachievable. On the contrary, one of the strengths of the use of HSPF models in drainage design is the ability to make relative comparisons (even on the order of changes of 15 cm or less), among various alternative management approaches.

In place of comparisons to model output to determine if there were unexpected changes in the hydrology of the UPD wetlands as a result of construction and development, the following metrics were calculated and trends over time were assessed by plotting each metric vs. time for each wetland monitoring location.

- Water level observed on or near June 30 (± 10 days).
- Spring/Summer (April-October) median water level.
- Winter (November-March) median water level.

In addition to the three metrics above, a metric that has been shown to be more directly related to wetland plant species richness and number of native amphibian species – Water Level Fluctuation (WLF) – was calculated (Azous *et al.* 2001). The WLF metric is also part of wetland protection guidance provided in the 2009 King County Surface Water Design Manual⁵. Generally, WLF is the average difference between the maximum depth (or elevation) and the average instantaneous depth (or elevation) in a time period. For a combination of instantaneous staff plate and crest-stage readings, WLF can be calculated as:

$$\text{WLF} = \text{Crest stage} - (\text{Instantaneous stage at beginning of interval} + \text{Instantaneous stage at end of interval})/2$$

For continuous stage records, WLF can be calculated as:

$$\text{WLF} = \text{Maximum stage during period} - \text{Average stage during period}$$

Because pre-development measurements were done on an approximately monthly basis, post-construction WLF was calculated and plotted on a monthly interval from the continuous stage data. An annual average WLF of 15 cm or less has been associated with higher wetland plant species richness and a WLF of 24 cm or less has been associated with higher amphibian species richness (Azous *et al.*, 2001).

In addition, the entire period of record represented by the individual staff gage readings or the daily average of the continuous stage readings were plotted to visually inspect the record for changes over time that might be attributable to the UPDs.

The choice of years in which to calculate metrics was somewhat complicated for periods when only staff readings were available because observations were not always made precisely on June 30 and there were sometimes only one (or no more than a few) observation made during the Spring/Summer or the Winter period defined above. Calculation and comparison of the wetland metrics pre- and post-development was further complicated for the seven Redmond Ridge wetland monitoring locations. The frequency of data collection at the Redmond Ridge wetlands varied between pre- and post-construction – generally monthly staff plate and crest stage observations during pre-development monitoring and continuous water level monitoring post construction.

⁵ Link to 2009 King County Surface Water Design Manual:
<http://www.kingcounty.gov/environment/waterandland/stormwater/documents/surface-water-design-manual.aspx>

3.2 Results

Figures illustrating trends in observed water levels and the selected metrics at the 12 monitored wetlands are provided in Appendix D through F. The wetland level monitoring results are presented by first discussing the monitoring results for the two Redmond Ridge wetlands that occur in basins that have not been fully developed. The remaining Redmond Ridge wetland monitoring results are then discussed followed by a discussion of the Trilogy UPD wetland level monitoring results.

Redmond Ridge BBC-52 and BBC-45

Two wetlands in the Redmond Ridge UPD occur in basins that have not been fully developed (BBC-52 and BBC-45) and therefore may serve to illustrate the changes (or lack thereof) that might be observed over time if wetland basins within the UPD had been left relatively undisturbed in their pre-construction condition. King County (2010) indicated that the outflow from BBC-52 is controlled by beaver dams. The water surface elevation of BBC-52 has appeared to shift gradually over time (Figure 9). Consequently, the inter-annual fluctuation of the June 30 water level, and the median spring/summer and winter water levels have also fluctuated beyond the wetland elevation targets established for modeling the effectiveness of stormwater management facilities on wetland levels (Figure 10). Although the variation in WLF in BBC-52 appears to be rather large (Figure 11), the mean WLF is 10 cm, which is typical of wetlands in relatively undeveloped basins (Azous et al., 2001). However, the frequency of excursions greater than 15 cm above the annual average appear to be rather more frequent than those typical of wetlands in relatively undeveloped basins (Azous et al. 2001). Unfortunately, pre-development monitoring at wetland BBC-52 and BBC-45 (and the other wetlands in the Redmond Ridge UPD) did not include crest stage gages, so pre-development WLF cannot be calculated for comparison.

Although wetland levels in BBC-45 appear to be rising since construction monitoring began in 2000 (Figure 12), the observed WLF has been well within that expected for a wetland in an undeveloped basin (Figure 13). King County (2010) indicated that the outflow from this wetland was controlled by a maintenance road along a power line right-of-way that was re-graded since the baseline monitoring period and suggested that the road bed elevation may have changed, resulting in alteration of the wetland hydrology.

Redmond Ridge EC-3, EC-61, EC-4, and BBC-UN1

The data from the four remaining wetlands that were monitored in the Redmond UPD all suggest some changes over time (see Figure 14 through Figure 17). Investigation of the outlet structures at three of these four wetlands was recommended by King County (2010). Relatively large water level fluctuations in wetland BBC-UN1 were also noted in that report. In fact, BBC-UN1 had one of the highest mean WLFs (37 cm) of all the monitored UPD wetlands (Figure 18). Mean WLFs at the other three wetlands (EC-3, EC-61, and EC-4) were below 15 cm, so changes in the outlet controls of these three wetlands appear to be the primary cause of changes in absolute wetland water levels. Because pre-development monitoring in the Redmond Ridge UPDs did not include crest stage gages, it is not possible to determine if the large mean WLF observed for the BBC-UN1 wetland is typical of WLF prior to developing the basin in which this wetland occurs.

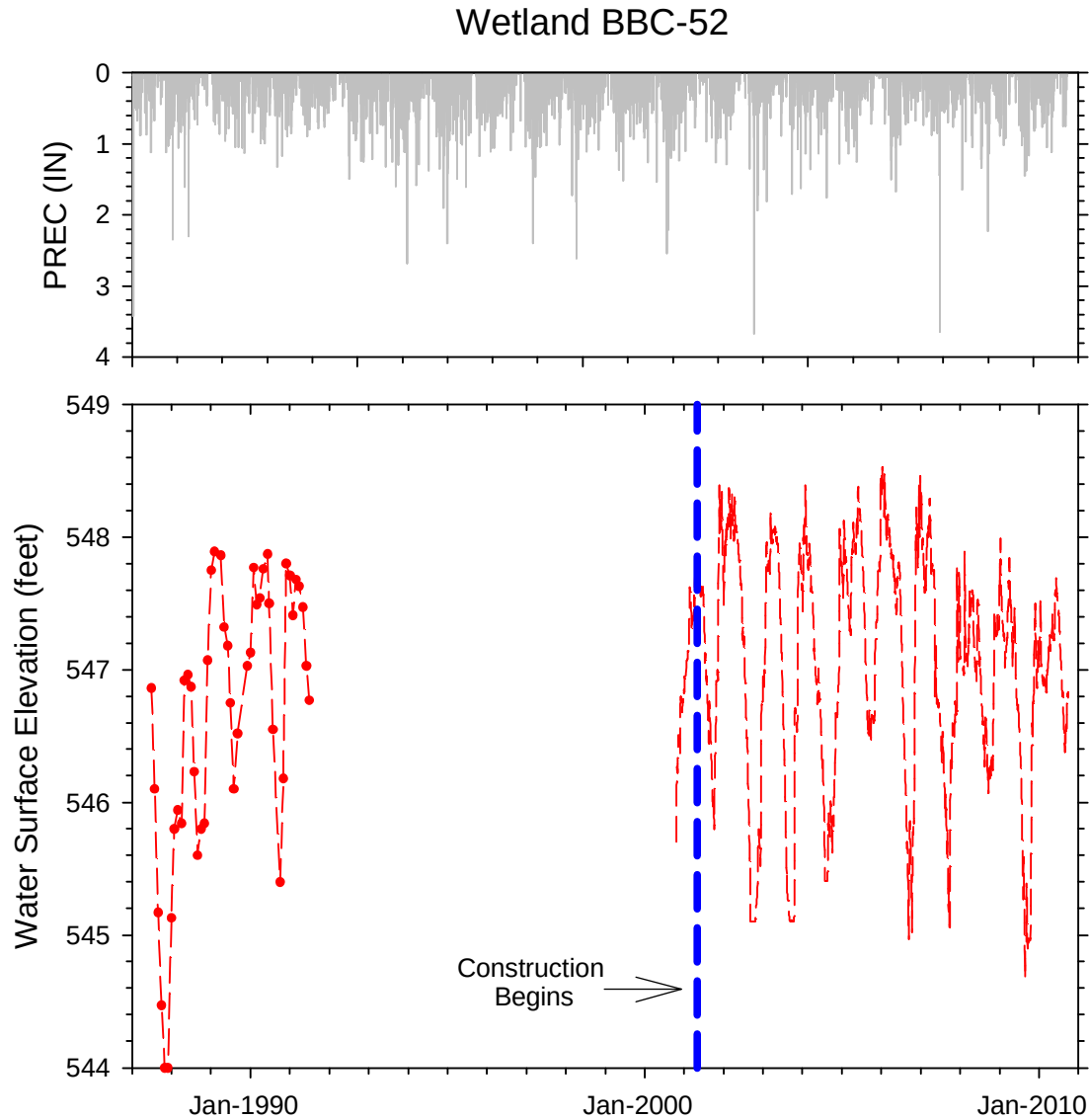


Figure 9. Observations of wetland water levels in Redmond Ridge wetland BBC-52.

Pre-development baseline based on instantaneous staff gage readings. Construction monitoring elevations are daily average elevations based on continuous stage readings. Top panel shows daily precipitation totals. The vertical dashed line indicates the initiation of construction. This basin has not reached the point of 75 percent buildout.

Wetland BBC-52

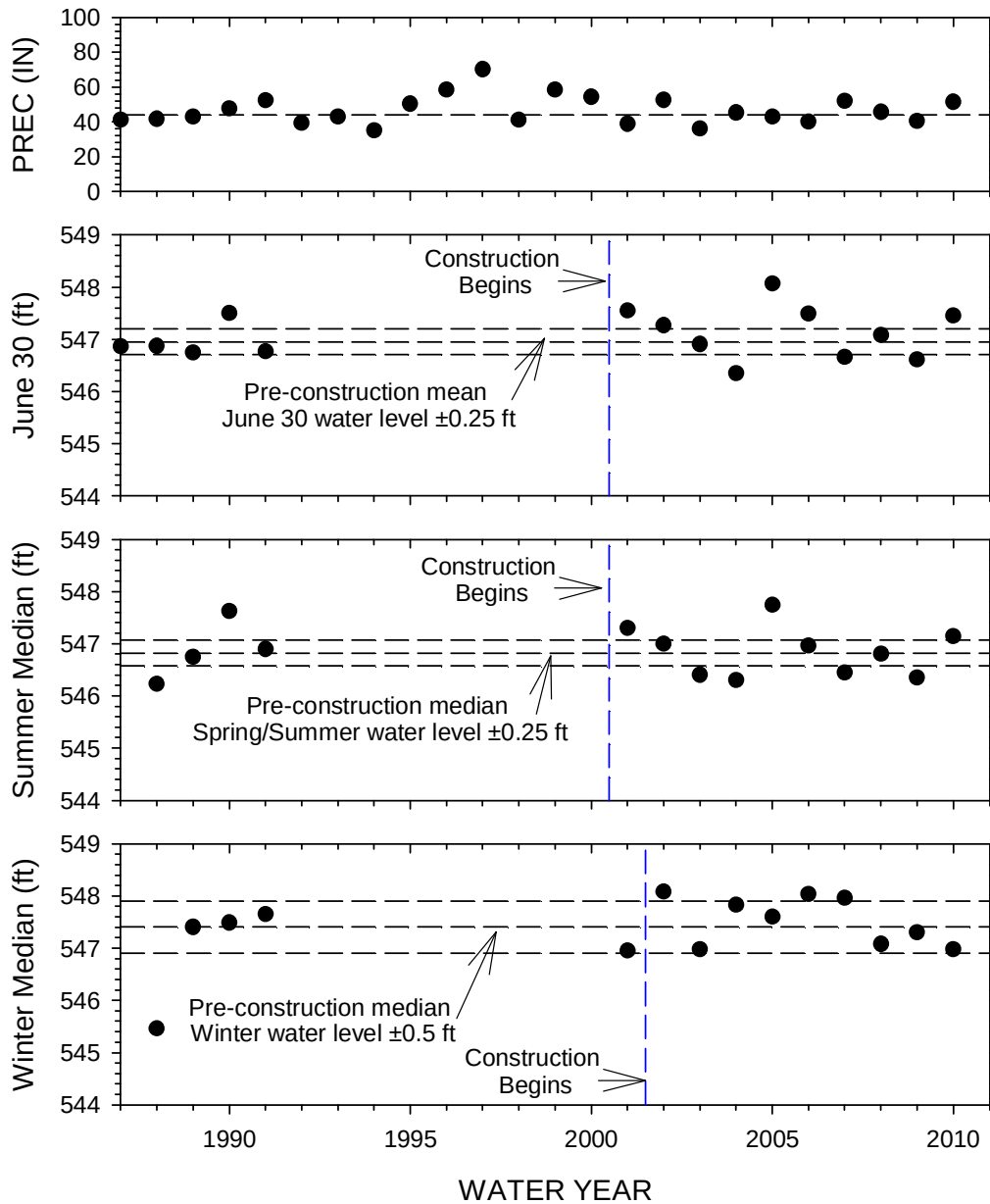


Figure 10. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland BBC-52.

Pre-development baseline estimates based on instantaneous staff gage readings. Construction monitoring estimates are based on daily average elevations from continuous stage readings. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2001. This basin has not reached the point of 75 percent buildout.

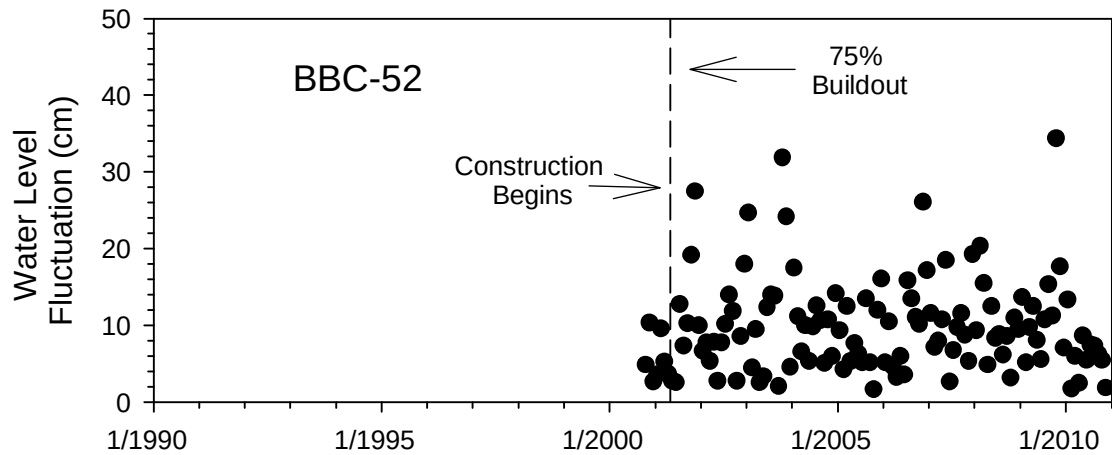


Figure 11. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-52. Pre-development estimates of WLF could not be made because only instantaneous staff gage readings were made during this period. Construction monitoring estimates are monthly based on continuous stage readings. The vertical dashed line indicates the initiation of construction. This basin has remained relatively undeveloped and has not reached the point of 75 percent buildout.

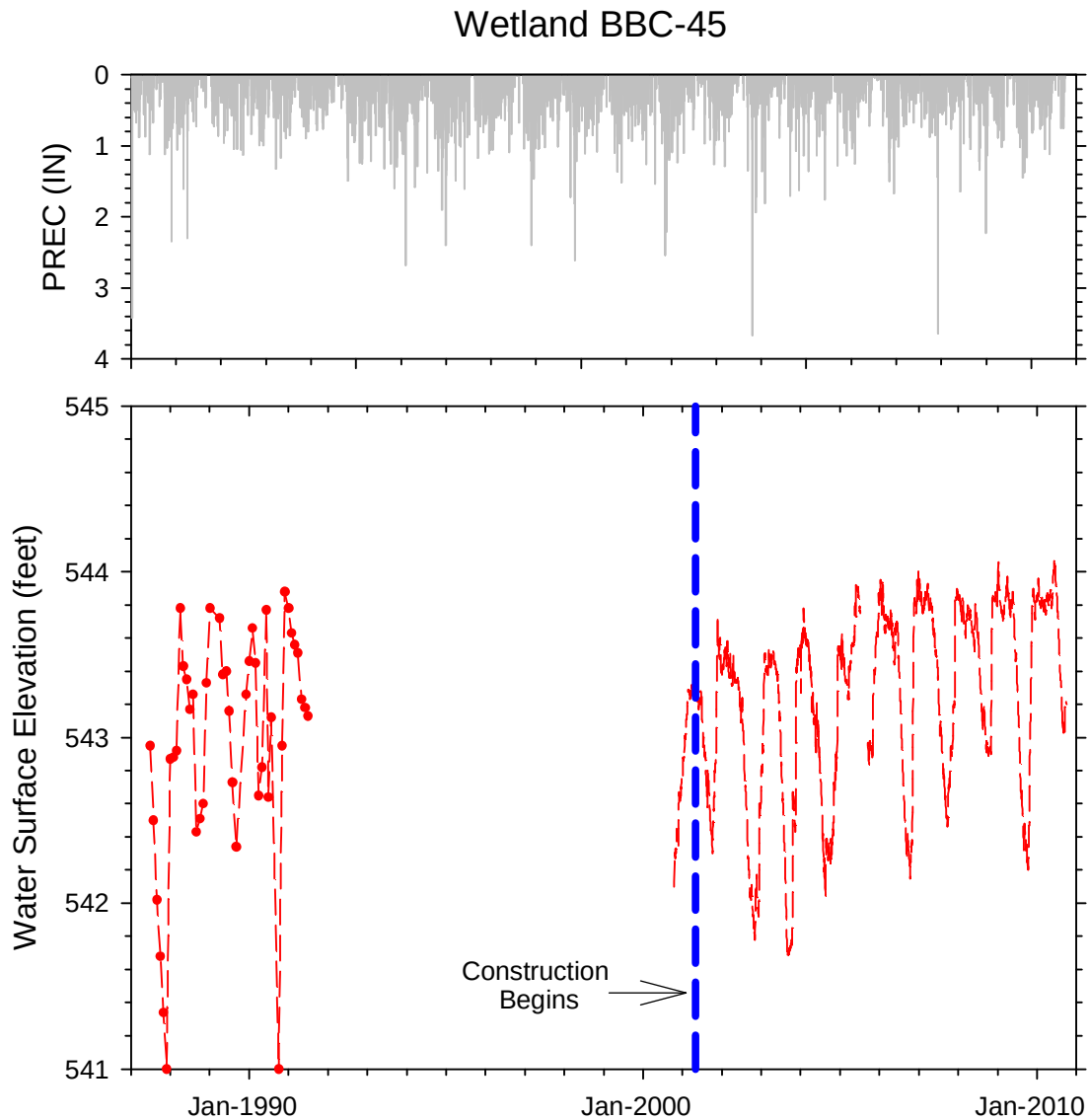


Figure 12. Observations of wetland water levels in Redmond Ridge wetland BBC-45.

Pre-development baseline based on instantaneous staff gage readings. Construction monitoring elevations are daily average elevations based on continuous stage readings. Top panel shows daily precipitation totals. The vertical dashed line indicates the initiation of construction. This basin has remained relatively undeveloped and has not reached the point of 75 percent buildout.

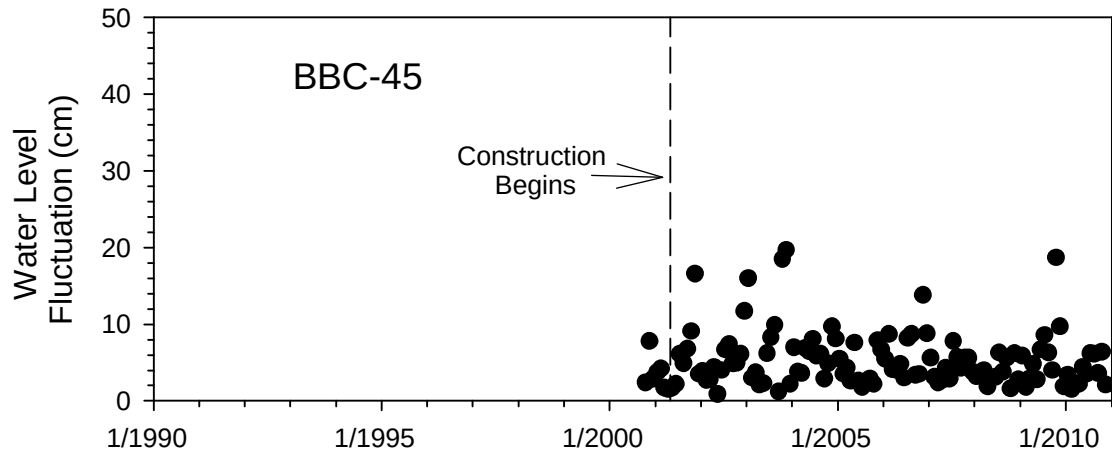


Figure 13. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-45. Pre-development estimates of WLF could not be made because only instantaneous staff gage readings were made during this period. Construction monitoring estimates are monthly based on continuous stage readings. The vertical dashed line indicates the initiation of construction. This basin has remained relatively undeveloped and has not reached the point of 75 percent buildout.

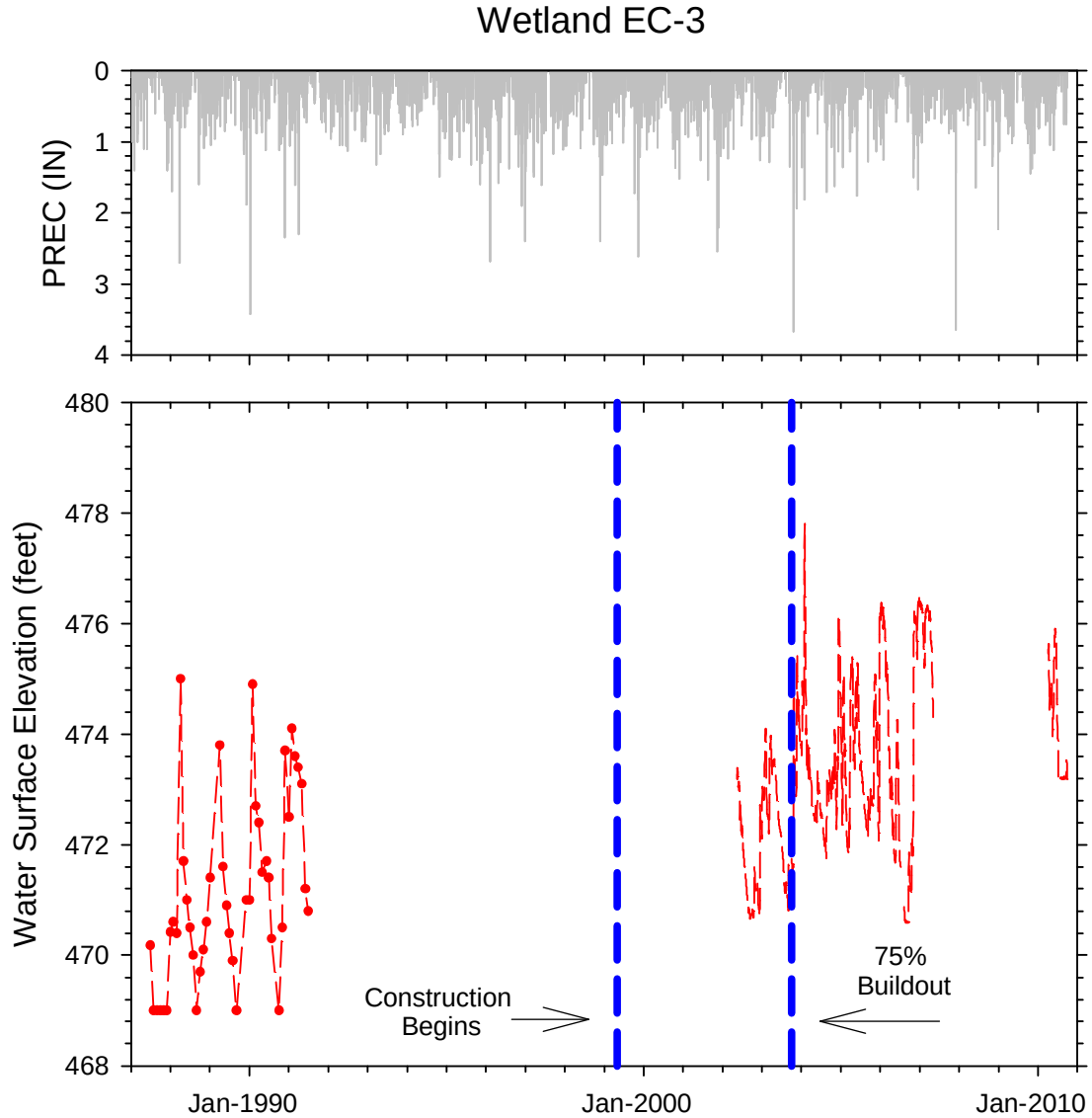


Figure 14. Observations of wetland water levels in Redmond Ridge wetland EC-3. Pre-development baseline based on instantaneous staff gage readings. Construction monitoring elevations are daily average elevations based on continuous stage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

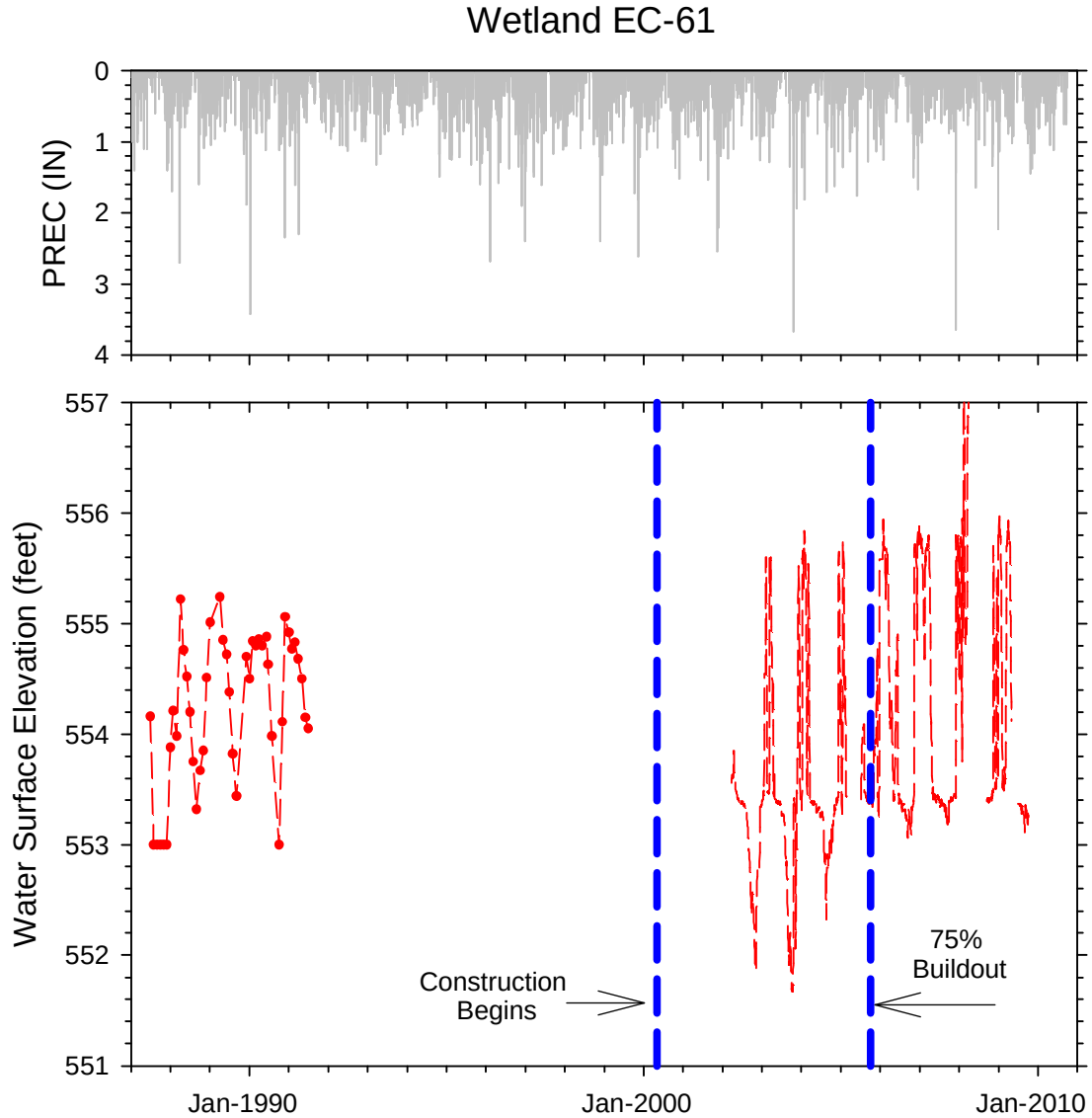


Figure 15. Observations of wetland water levels in Redmond Ridge wetland EC-61. Pre-development baseline based on instantaneous staff gage readings. Construction monitoring elevations are daily average elevations based on continuous stage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

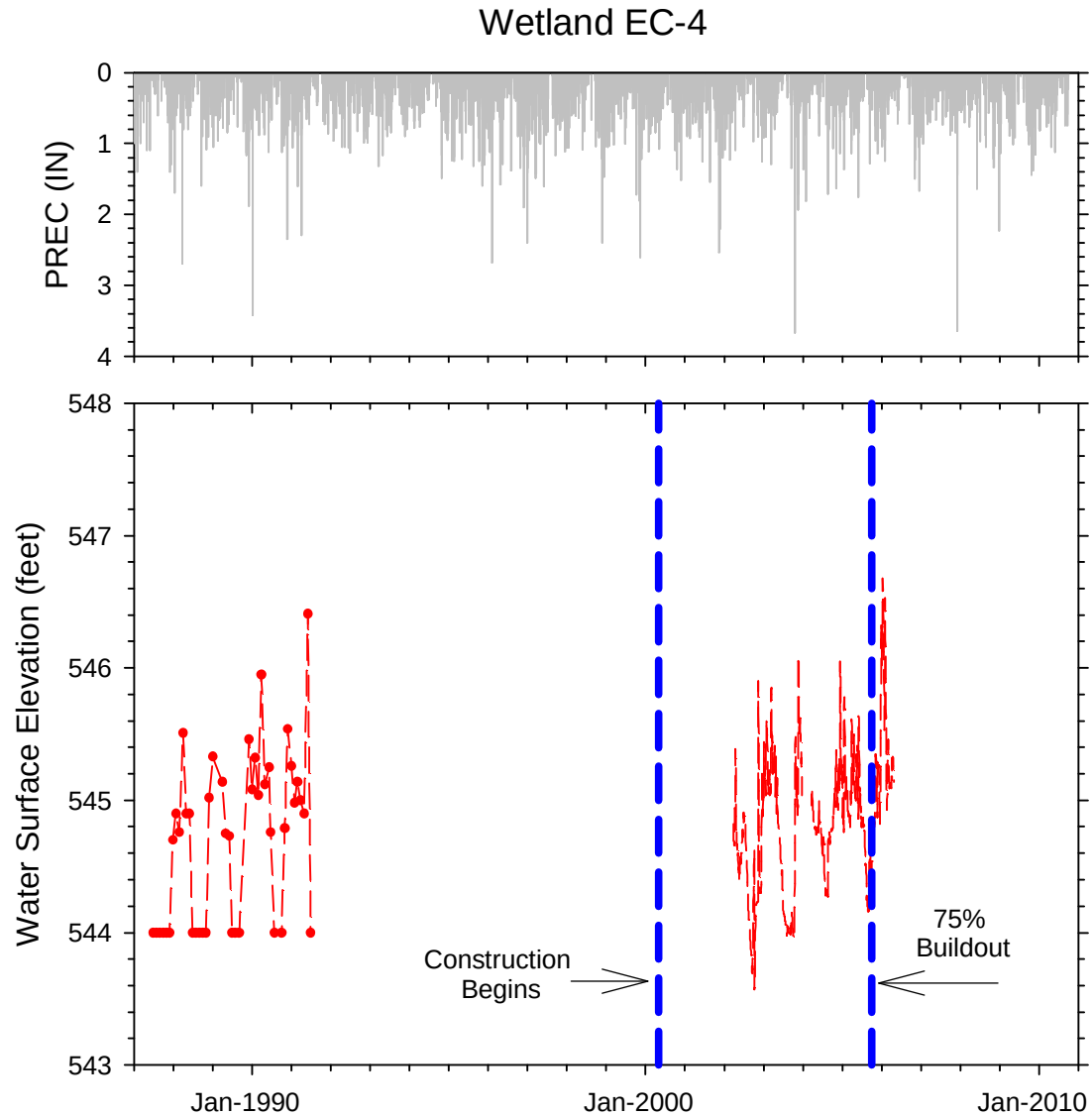


Figure 16. Observations of wetland water levels in Redmond Ridge wetland EC-4. Pre-development baseline based on instantaneous staff gage readings. Construction monitoring elevations are daily average elevations based on continuous stage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

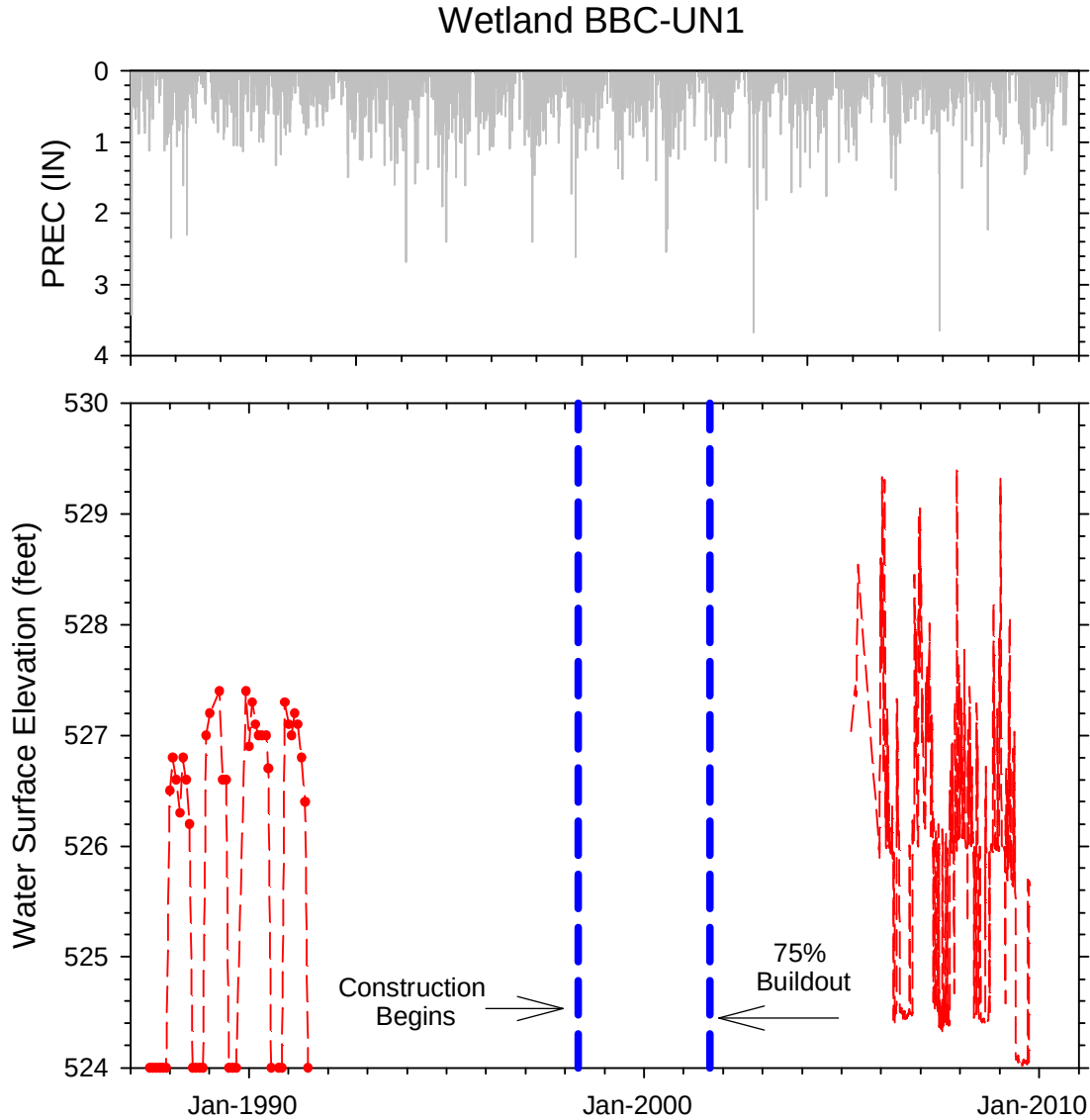


Figure 17. Observations of wetland water levels in Redmond Ridge wetland BBC-UN1. Pre-development baseline based on instantaneous staff gage readings. Construction monitoring elevations are daily average elevations based on continuous stage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

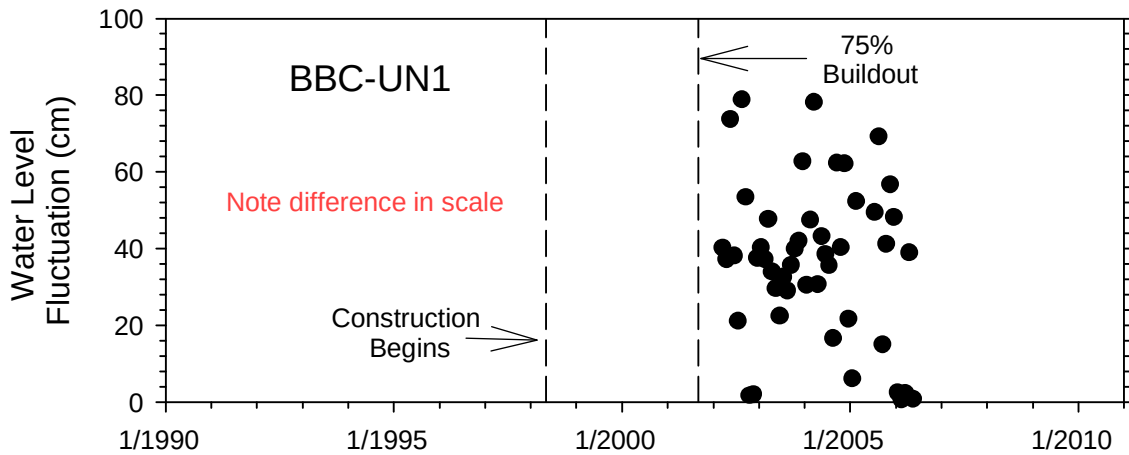


Figure 18. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-UN1. Pre-development estimates of WLF could not be made because only instantaneous staff gage readings were made during this period. Construction monitoring estimates are monthly based on continuous stage readings. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Trilogy BBC-45A, BBC-26, SR-24A, and SR-24C

These four wetlands have instantaneous and crest stage data for the pre-development baseline and subsequent development period that allow for an evaluation of development effects on WLFs in these wetlands (Figure 19). With the exception of the trend in WLFs in BBC-26, the available data suggest that WLFs increased following buildout – post-construction WLFs in BBC-26 appear to have decreased. Although WLFs appear to have decreased over time in BBC-26, the upward trend in mean water levels noted by King County (2010) has continued (Figure 20). The apparent changes in WLFs at SR-24A and SR-24C are high enough to expect some effect on plant and/or amphibian species richness (Azous *et al.* 2001). However, it should be noted that the estimated changes are based on only two post-development WLF observations in SR-24A and the estimate of post-development WLFs in SR-24C is based on only a few data points biased significantly by the last WLF estimate of 96 cm. No UPD wetland vegetation monitoring was conducted in these wetlands. However, amphibian monitoring was conducted in BBC-26 and SR-24C. The only change noted following construction in these two wetlands was a post-construction decline in Pacific treefrog egg mass abundance in SR-24C, although declines were also noted in the relatively undeveloped wetland BBC-52 (King County 2011).

Trilogy BBC-44 and SR-24B

Baseline pre-construction data are not available for these two wetlands, so assessment of the potential effect of development on these wetlands is further complicated. However, post-development WLFs in these wetlands are relatively low – less than 10 cm on average (Figure 21), which suggests minimal effects from development (Azous *et al.* 2001).

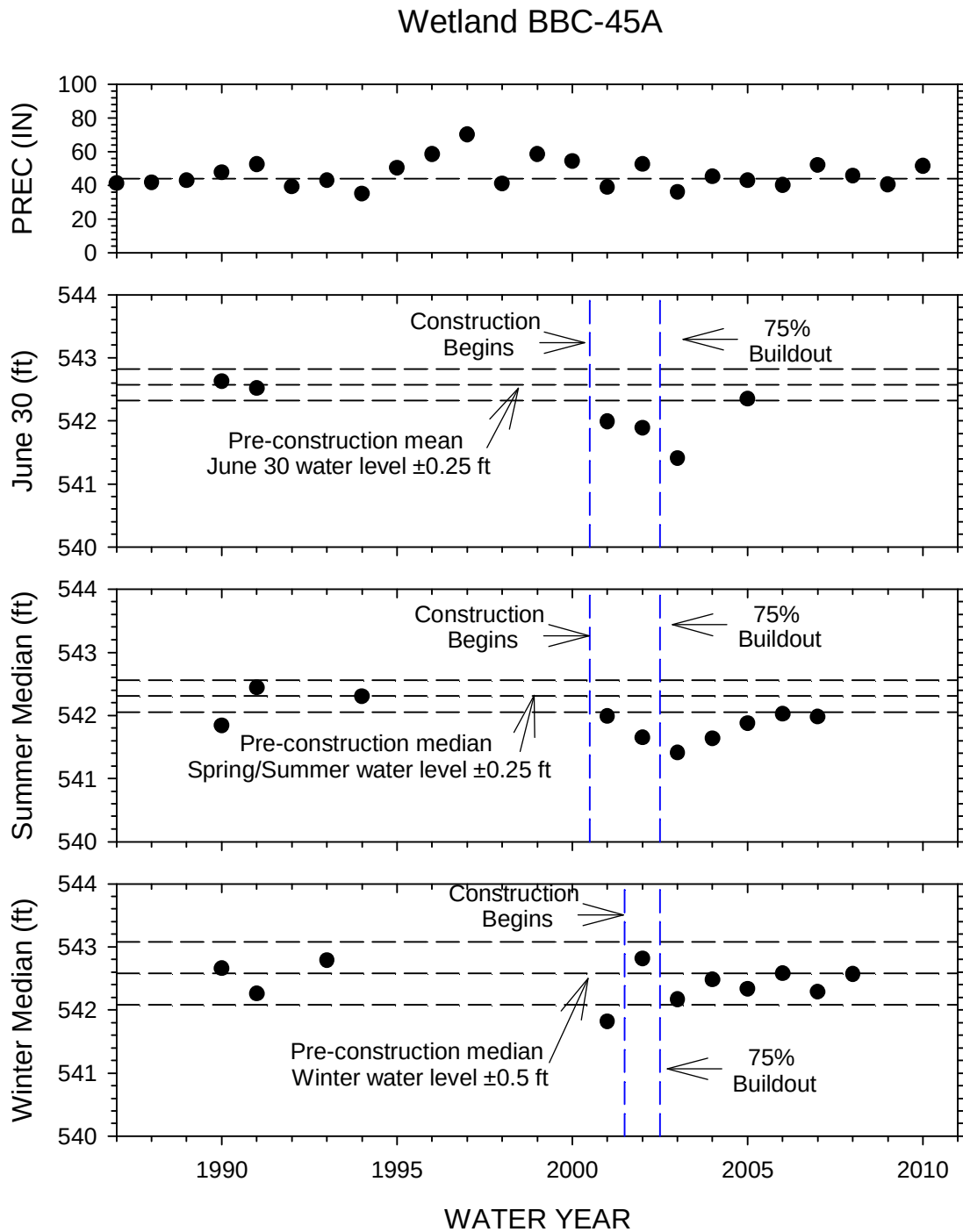


Figure 19. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetlands BBC-45A, BBC-26, SR-24A and SR-24C.

Pre-development and post-construction estimates of WLF are based on instantaneous and crest stage gage observations made approximately monthly. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

Wetland BBC-26

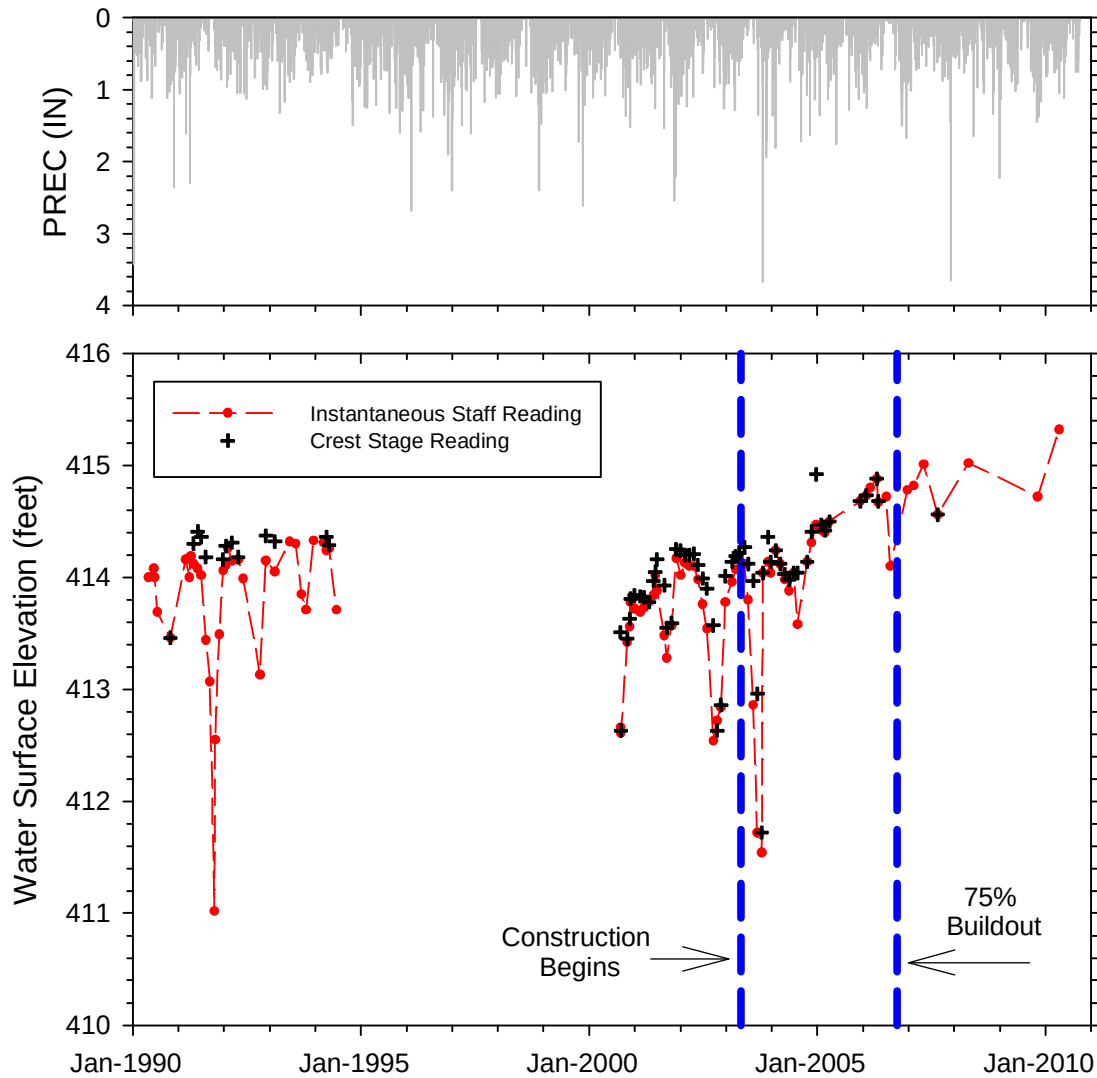


Figure 20. Observations of wetland water levels in Trilogy wetland BBC-26.

Pre-development baseline and construction phase monitoring based on instantaneous staff and crest stage gage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

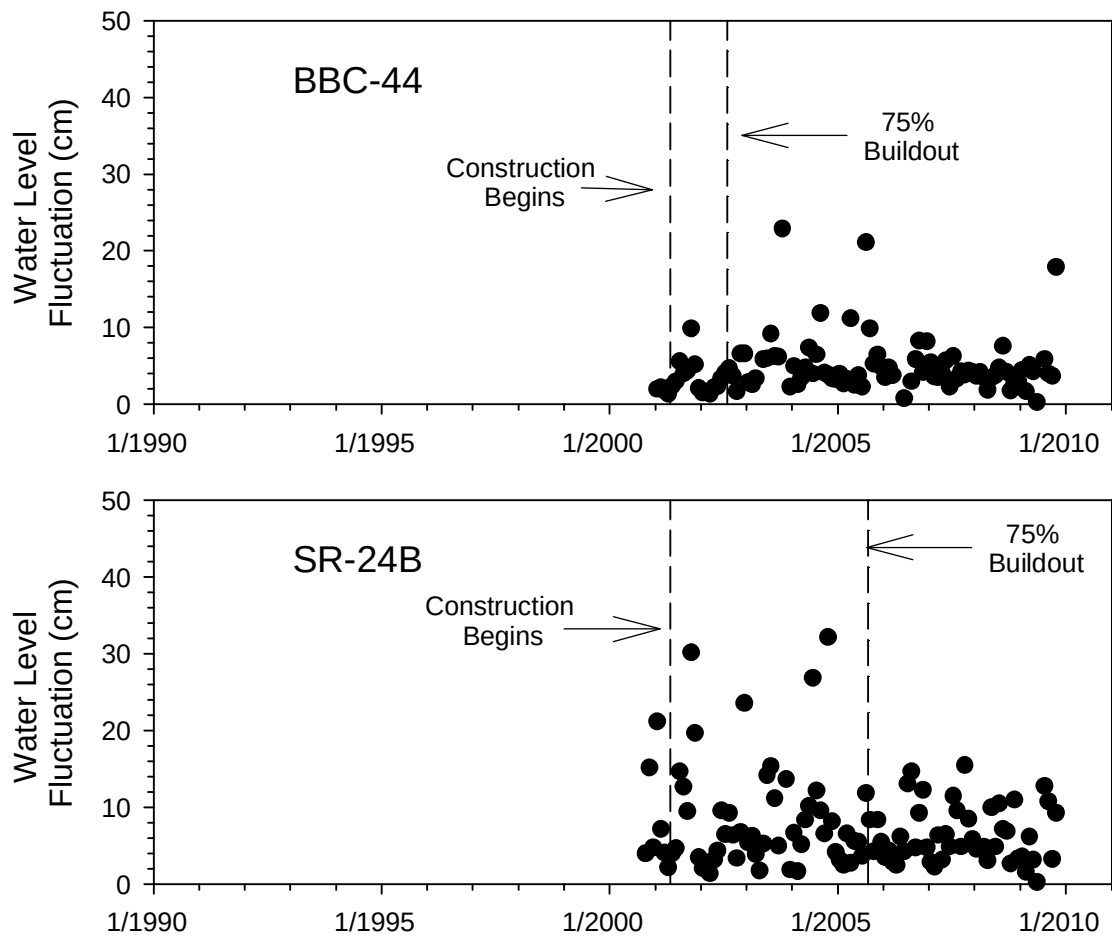


Figure 21. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetlands BBC-44 and SR-24B. No Pre-development data are available for these gages. Monthly post-construction estimates of WLF are based on continuous gage observations. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

3.3 Summary

In general, the hydrology of several of the wetlands appears to have changed over time, although the variety of sampling methods used (and the lack of any pre-development data at two wetlands) made it difficult to determine if these changes were related to UPD development. In many cases, outlet modifications due to alteration through road berm changes and beaver activity were likely causes of observed changes in water levels (King County 2010). It is not possible to connect any of the apparent changes to biological effects because the best documented biological connection with wetland water levels is with wetland plant species richness (Azous *et al.* 2001) – which was monitored in only one UPD wetland that did not ultimately undergo full (> 75% buildout) development during the monitoring program. The next strongest documented link between wetland water levels and biology is with amphibian species richness. The only notable change in amphibians that coincided with a relatively large shift in WLF following construction was in wetland SR-24C. A decline in Pacific treefrog egg mass abundance in that wetland coincided

with 75% buildout. However, a decline in egg mass abundance was also noted in the relatively undeveloped wetland BBC-52 that did not show any shift in WLFs during the same time period. Based on the available data, there does not appear to be compelling evidence that the development of the UPDs resulted changes in wetland water levels that resulted in biological changes. Unfortunately, other wetlands with apparent increases in WLFs (e.g., BBC-45A and SR-24A) were not monitored for biological changes.

3.4 Corrective Actions

No corrective actions are recommended for the wetland hydrology component of the monitoring plan. However, the available data suggest that the mean wetland levels in BBC-26 may have increased between 2005 and 2010 even though WLFs remained low post development. There is no obvious link to rising BBC-26 water levels and UPD development, and observed beaver activity near the wetland outlet may be responsible for the increased wetland height. No roads or houses are threatened at current wetland levels and future monitoring is beyond the scope of the UPD monitoring project.

Although WLFs in BBC-26 remained low post-development, the available data suggest that the mean wetland levels are increasing. It may be prudent to visually inspect the outlet of this wetland to determine if the outlet has been modified resulting in increased storage in this wetland. If it appears that the levels will continue to rise, it may be advisable to initiate a study to evaluate alternatives to restoring the wetland water level to a lower level or maintaining the current level.

4.0 REFERENCES

- Azous, A.L., L.R. Reinelt, and J. Burkey. 2001. Managing wetland hydroperiod: Issues and concerns. pp. 287-298. In. Azous, A. and R.R. Horner, editors. *Wetlands and Urbanization: Implications for the Future*. Lewis Publishers, Boca Raton, Florida.
- Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jr., Donigan, A.S., Jr. and Johanson, R.C., 2005, Hydrological Simulation Program -- FORTRAN, User's manual for version 12.2: U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, Georgia.
- Booth, D.B., J.R. Karr, S. Schauman, C.P. Konrad, S.A. Morley, M.G. Larson, and S.J. Burges. 2004. Reviving urban streams: Land use, hydrology, biology, and human behavior. *Journal of the American Water Resources Association* 40:1351-1364.
- DeGasperi, C.L., H.B. Berge, K.R. Whiting, J.J. Burkey, J.L. Cassin, and R.R. Fuerstenberg. 2009. Linking hydrologic alteration to biological impairment in urbanizing streams of the Puget Lowland, Washington, USA. *Journal of the American Water Resources Association* 45:512-533.
- Hugh G. Goldsmith & Associates. 1996. Northridge UPD/FCC Urban Planned Development Master Drainage Plan (MDP). Prepared for Quadrant Corporation, Bellevue, Washington. Prepared by Hugh G. Goldsmith & Associates, Inc., Bellevue, Washington.
- Helsel, D.R. and R. M. Hirsch, 2002. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, chapter A3. U.S. Geological Survey. 522 pages.
- Hartley, D.M and D.E. Funke. 2001. Techniques for detecting hydrologic change in high resource streams. *Journal of the American Water Resources Association* 37:1589-1595.
- King County. 1999. Redmond Ridge monitoring plan. Water and Land Resources Division, Seattle, Washington.
- King County. 2001. Post-Development Monitoring Plan for the Trilogy at Redmond Ridge (formerly Blakely Ridge) Urban Planned Development (UPD). Water and Land Resources Division, Seattle, Washington.
- King County. 2006. Trilogy and Redmond Ridge Urban Planned Development (UPD) Natural Resources Monitoring Midpoint Review. Prepared by Jennifer O. Wilhelm, Raymond K. Timm, Klaus O. Richter, Sally Abella, Kyle Comanor, David Funke, and Kenneth Johnson. Water and Land Resources Division, Seattle, Washington.
- King County. 2010. Trilogy and Redmond Ridge Urban Planned Development (UPD) annual Monitoring Report: Water year 2007. Prepared by Jo Wilhelm, Scott Stalnack, David Funke, and Ray Timm. Water and Land Resources Division, Seattle, Washington.

King County. 2011. Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Biological, Physical, and Chemical Monitoring for Water Years 2008-2010. Prepared by Jo Wilhelm and Sally Abella. Water and Land Resources Division, Seattle, Washington.

Northwest Engineering Company. 1995. Drainage Master Plan Blakely Ridge UPD. Prepared for Blakely Ridge Limited Partnership, Issaquah, Washington. Prepared by Northwest Engineering Company, Bellevue, Washington.

Otak, Inc. 2007. Final, Corrected. HSPF Model for Trilogy at Redmond Ridge (April 19, 2007). Prepared for Quadrant Homes, Bellevue, Washington. Otak, Inc., Kirkland, Washington.

5.0 APPENDICES

Appendix A. Peak flows

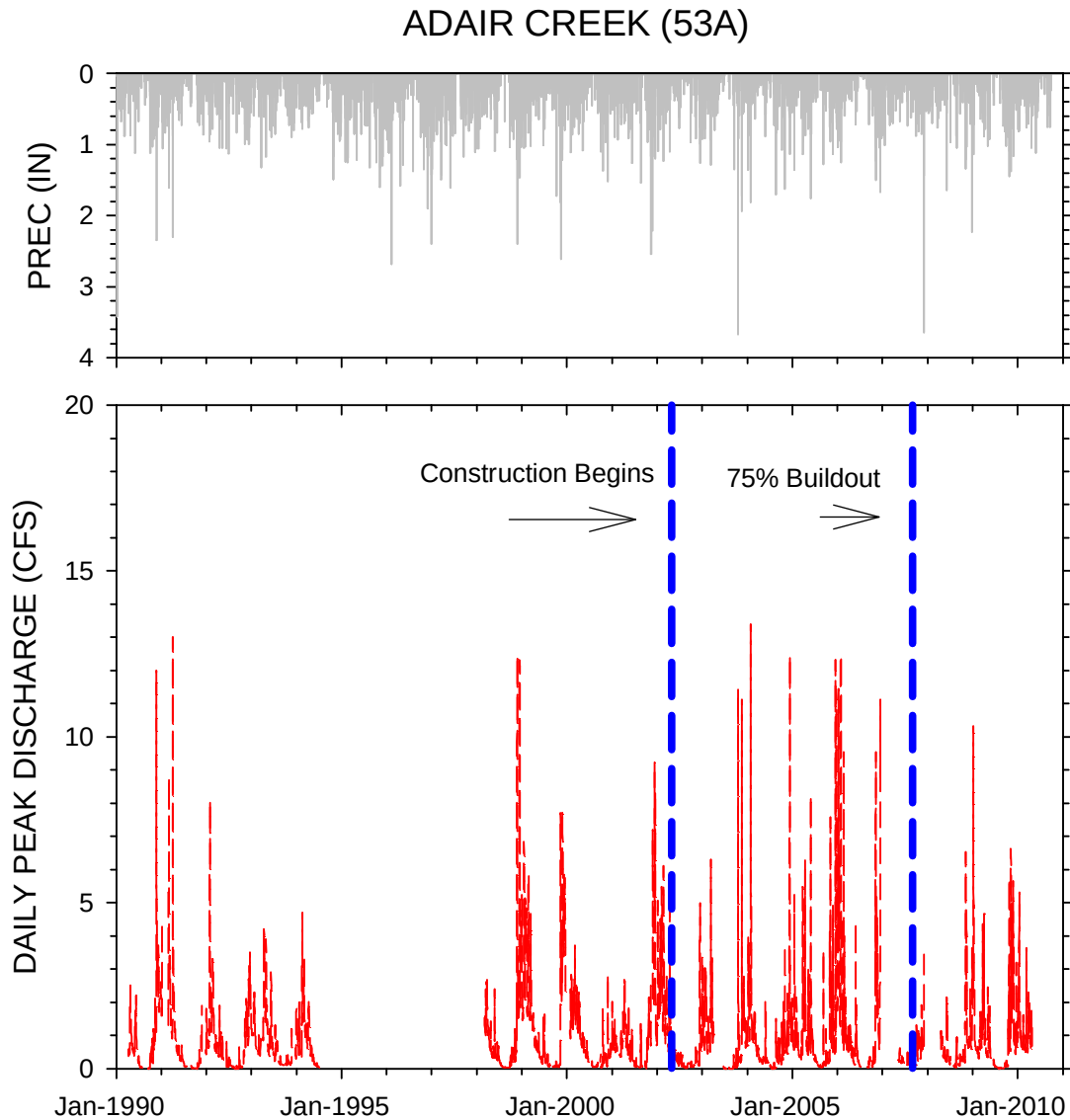


Figure A-1. Daily maximum discharge observed at the Adair Creek (53A) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NE basin.

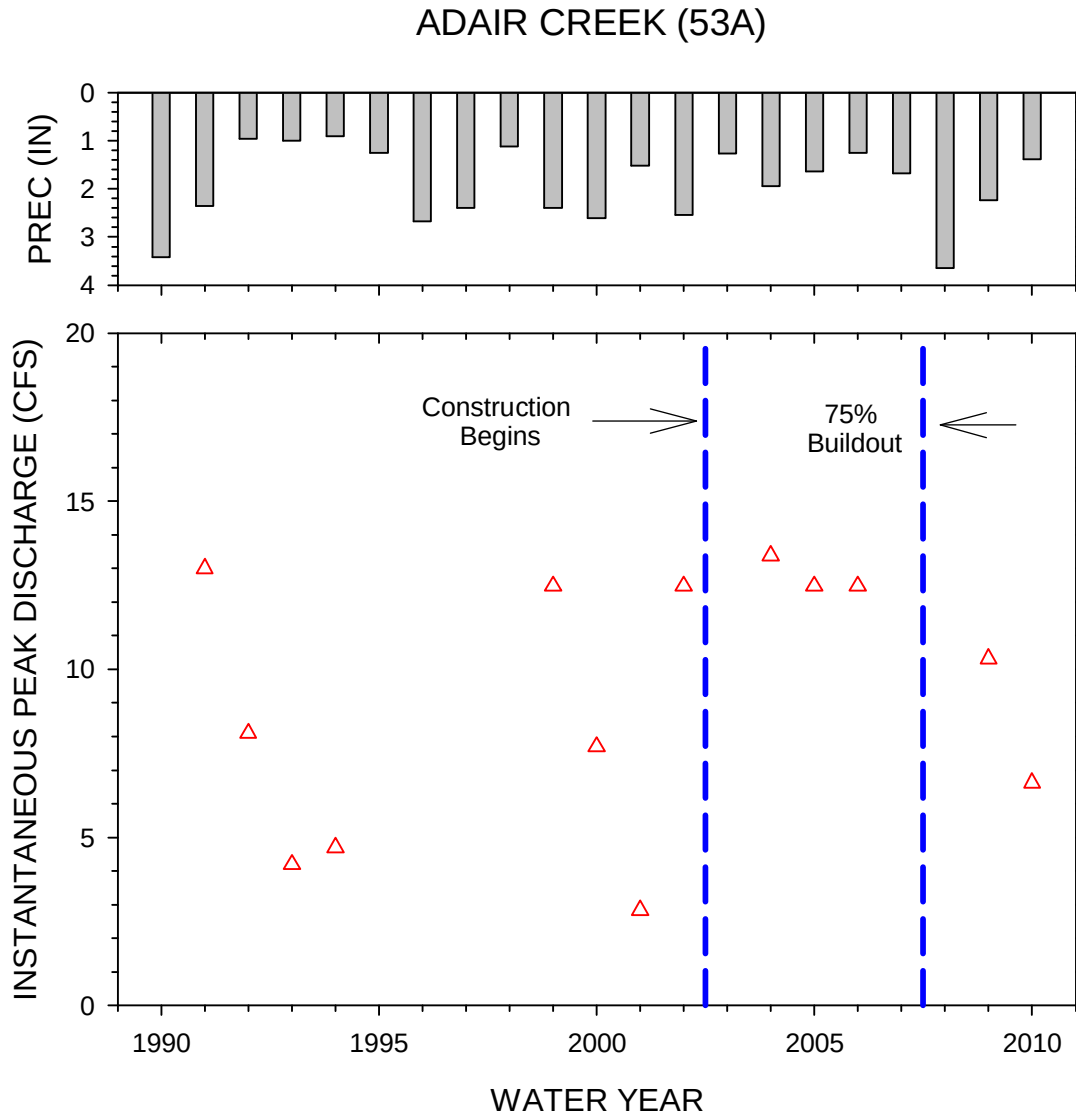


Figure A-2. Annual maximum discharge observed at the Adair Creek (53A) gage. Top panel shows maximum daily precipitation observed during the period Nov-Feb. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NE basin.

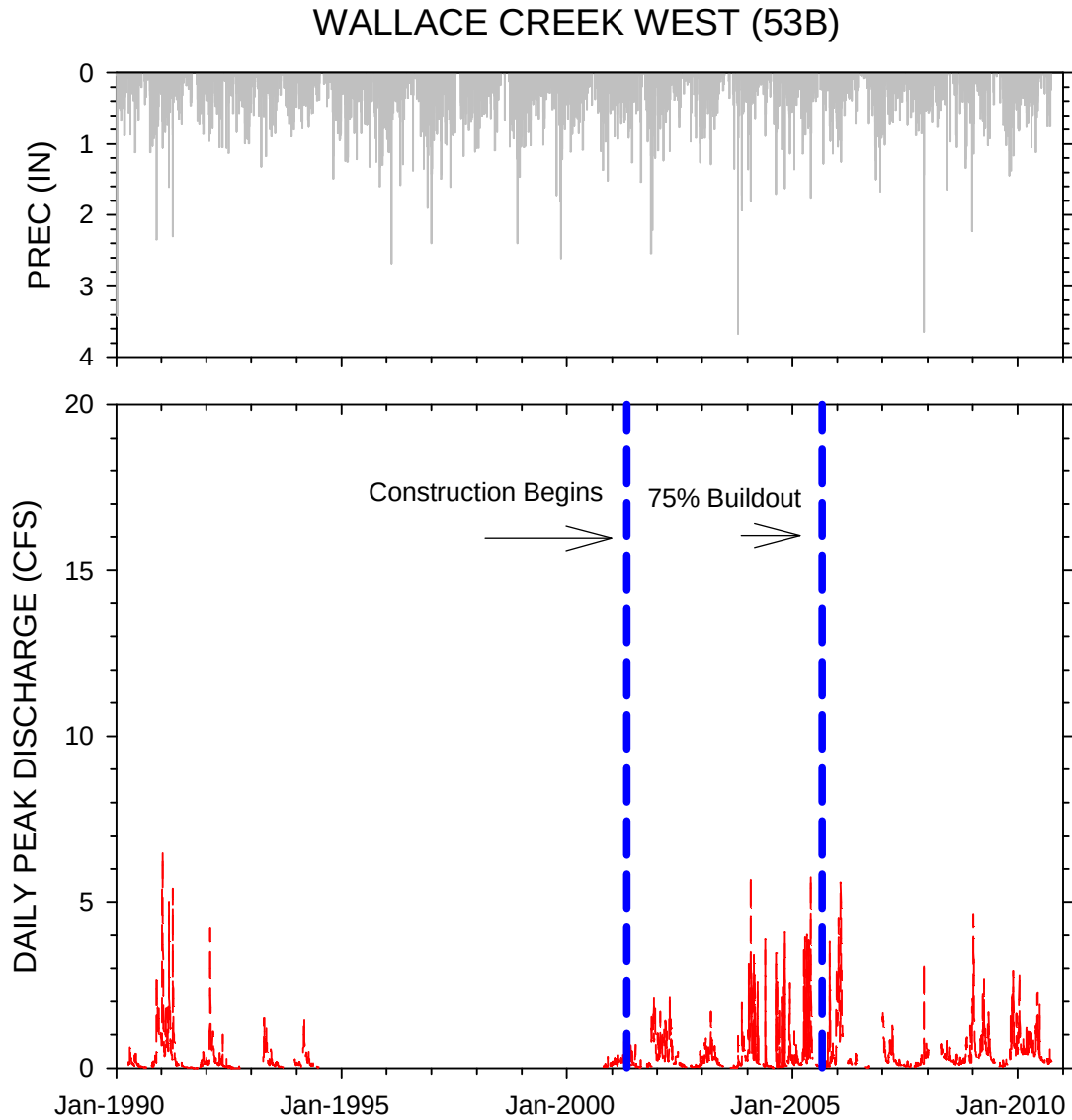


Figure A-3. Daily maximum discharge observed at the Wallace Creek West (53B) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SE basin.

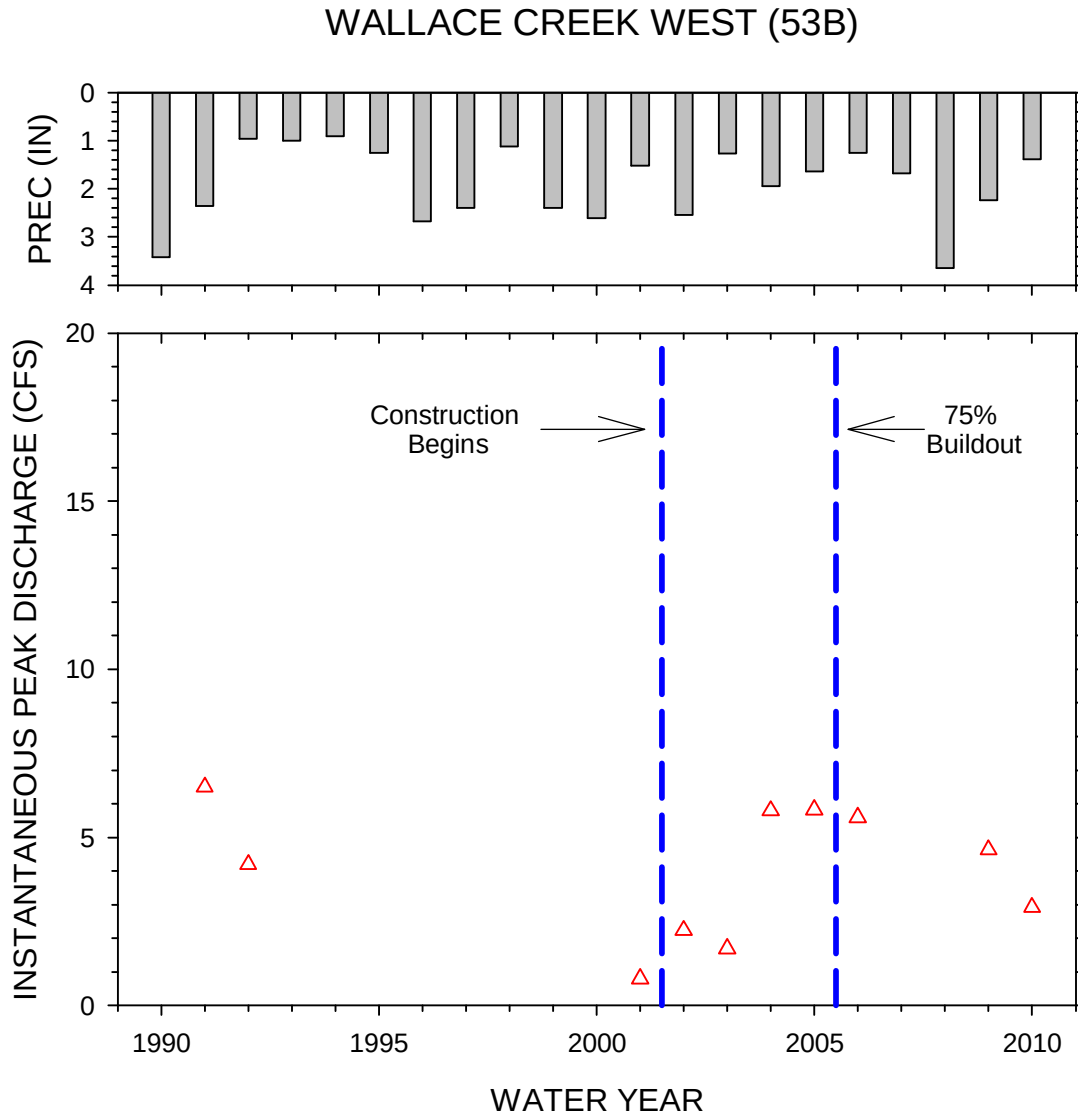


Figure A-4. Annual maximum discharge observed at the Wallace Creek West (53B) gage. Top panel shows maximum daily precipitation observed during the period Nov-Feb. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SE basin.

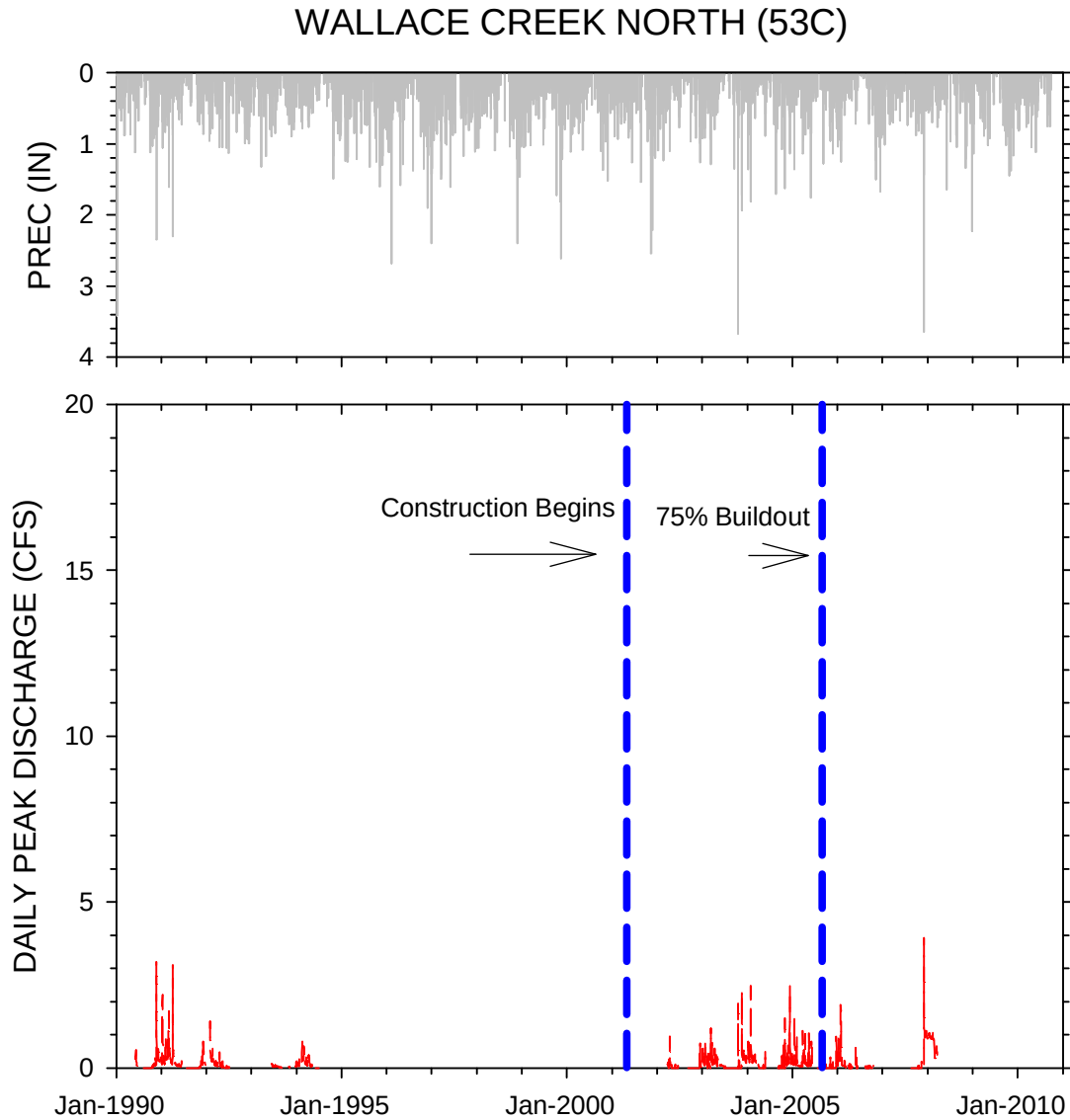


Figure A-5. Daily maximum discharge observed at the Wallace Creek North (53C) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SE basin.

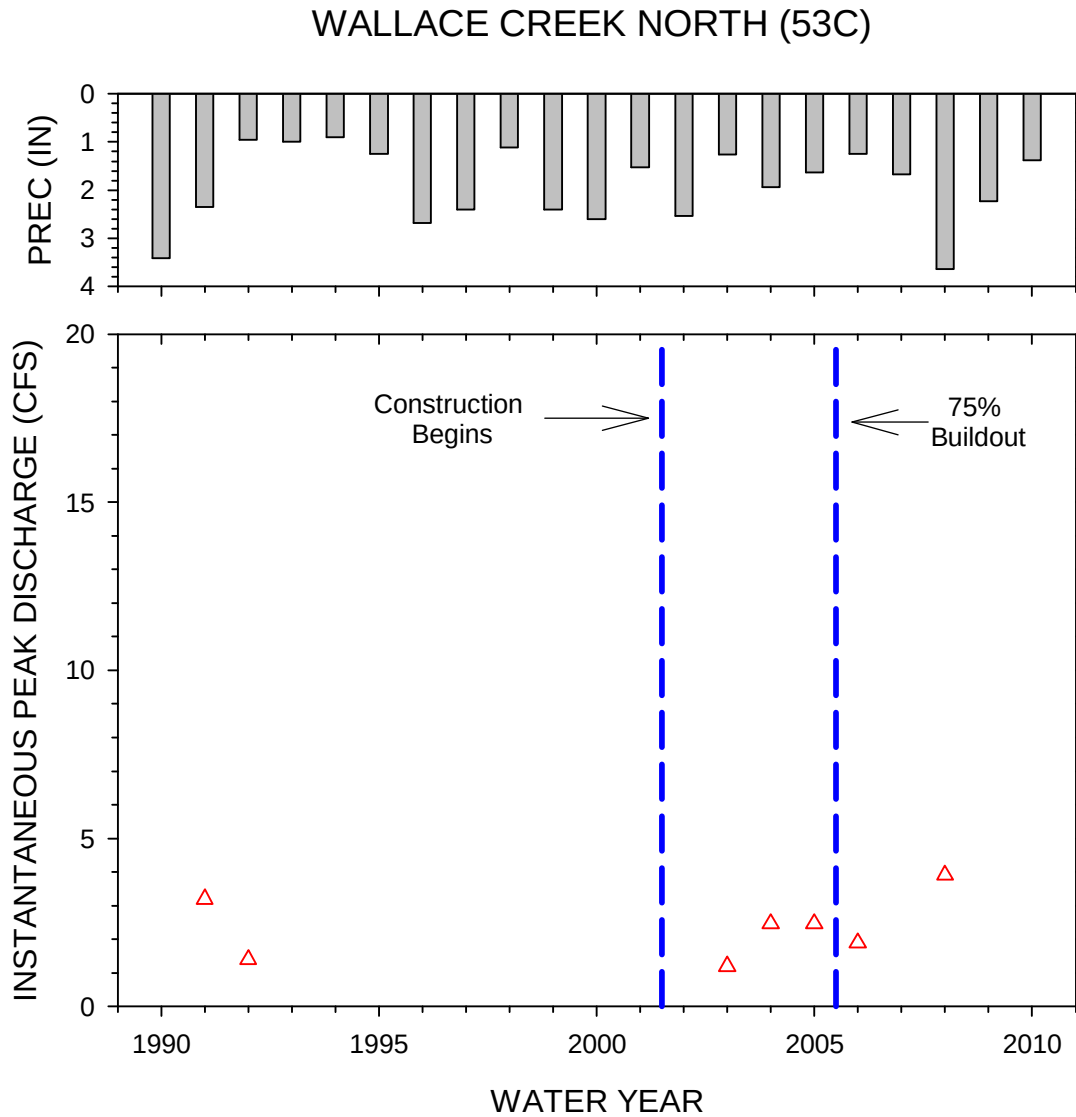


Figure A-6. Annual maximum discharge observed at the Wallace Creek North (53C) gage. Top panel shows maximum daily precipitation observed during the period Nov-Feb. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SE basin.

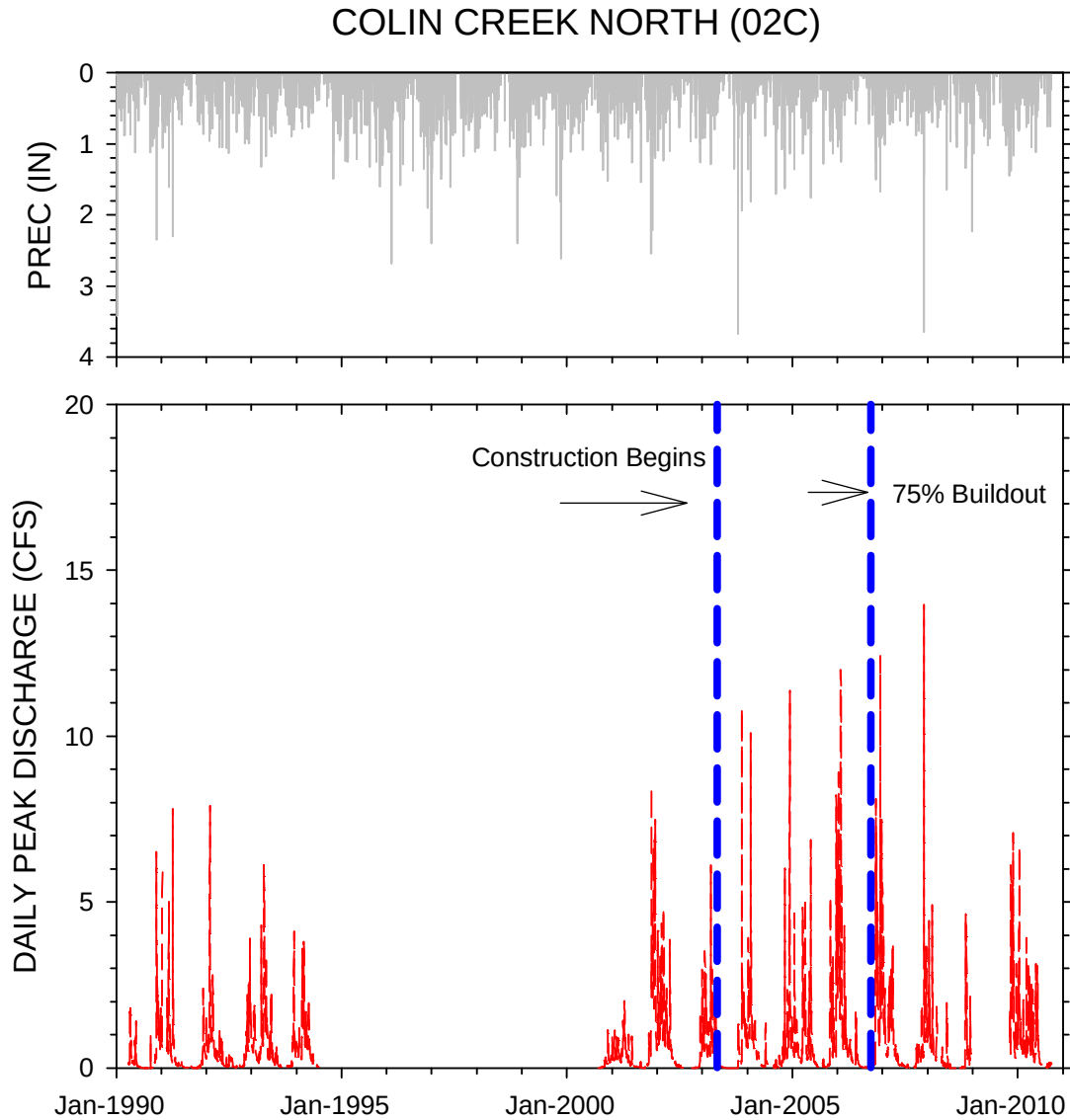


Figure A-7. Daily maximum discharge observed at the Colin Creek North (02C) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NW basin.

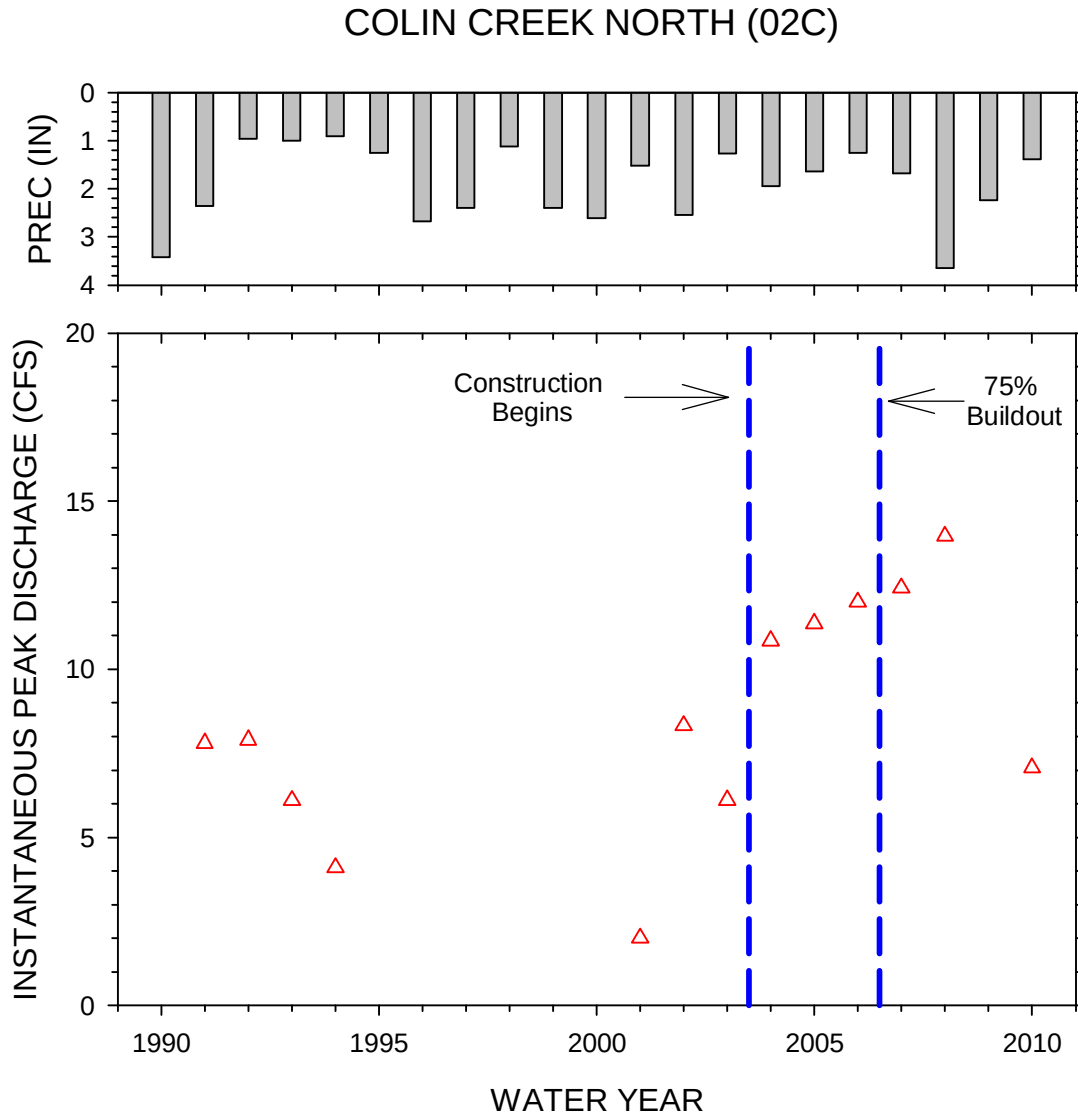


Figure A-8. Annual maximum discharge observed at the Colin Creek North (02C) gage. Top panel shows maximum daily precipitation observed during the period Nov-Feb. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NW basin.

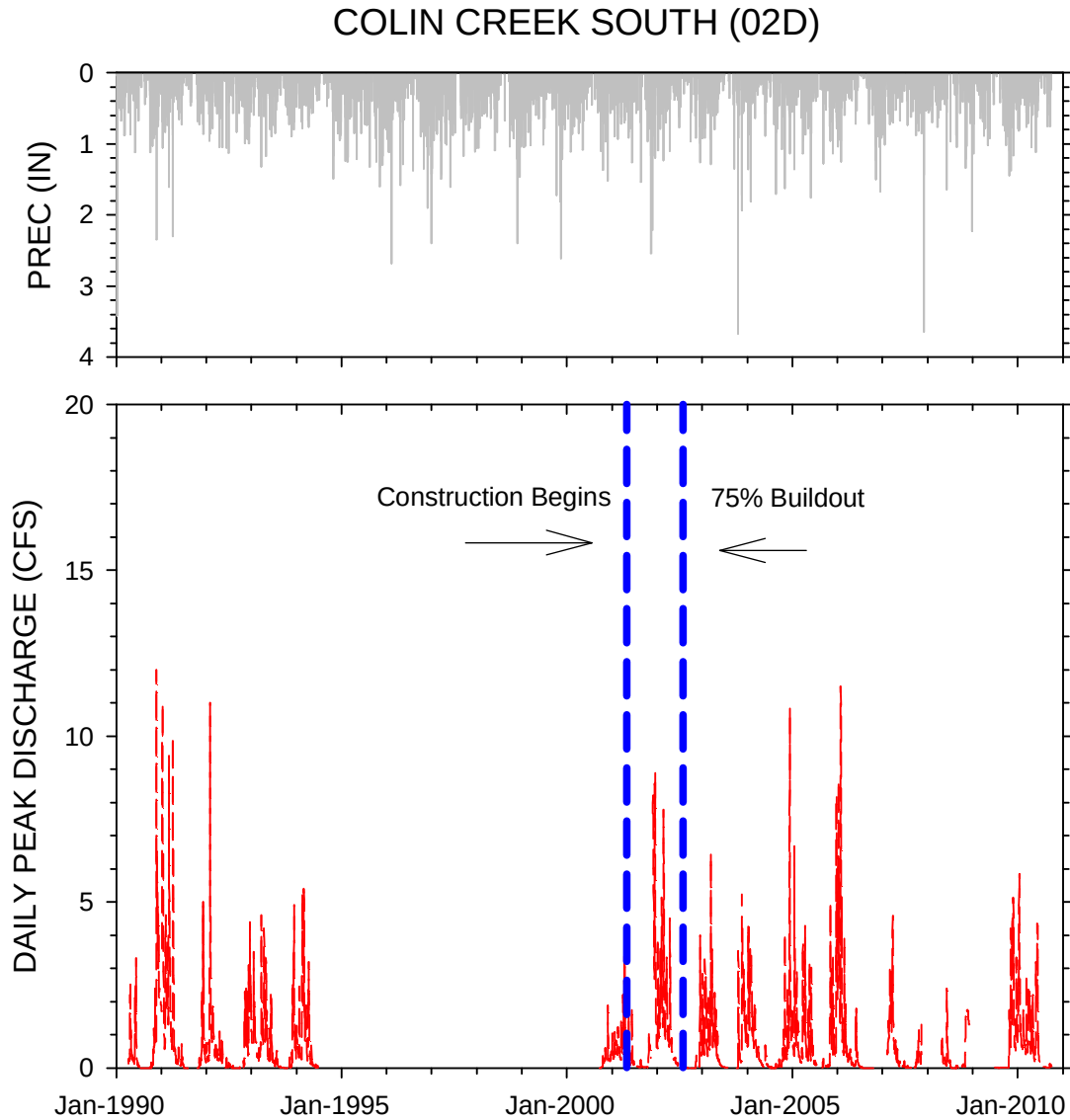
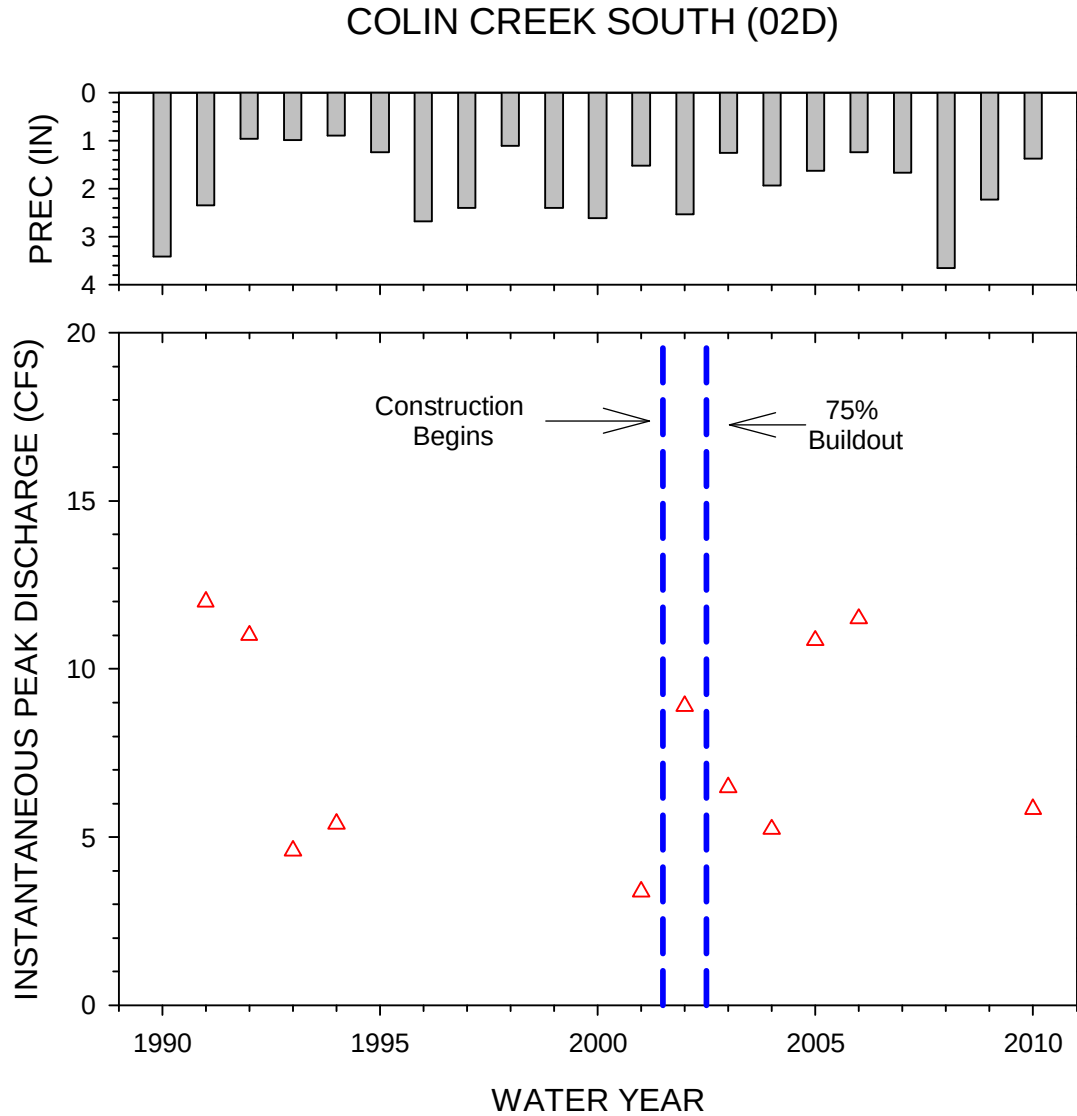


Figure A-9. Daily maximum discharge observed at the Colin Creek South (02D) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SW basin.



FigureA-10. Daily maximum discharge observed at the Colin Creek South (02D) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SW basin.

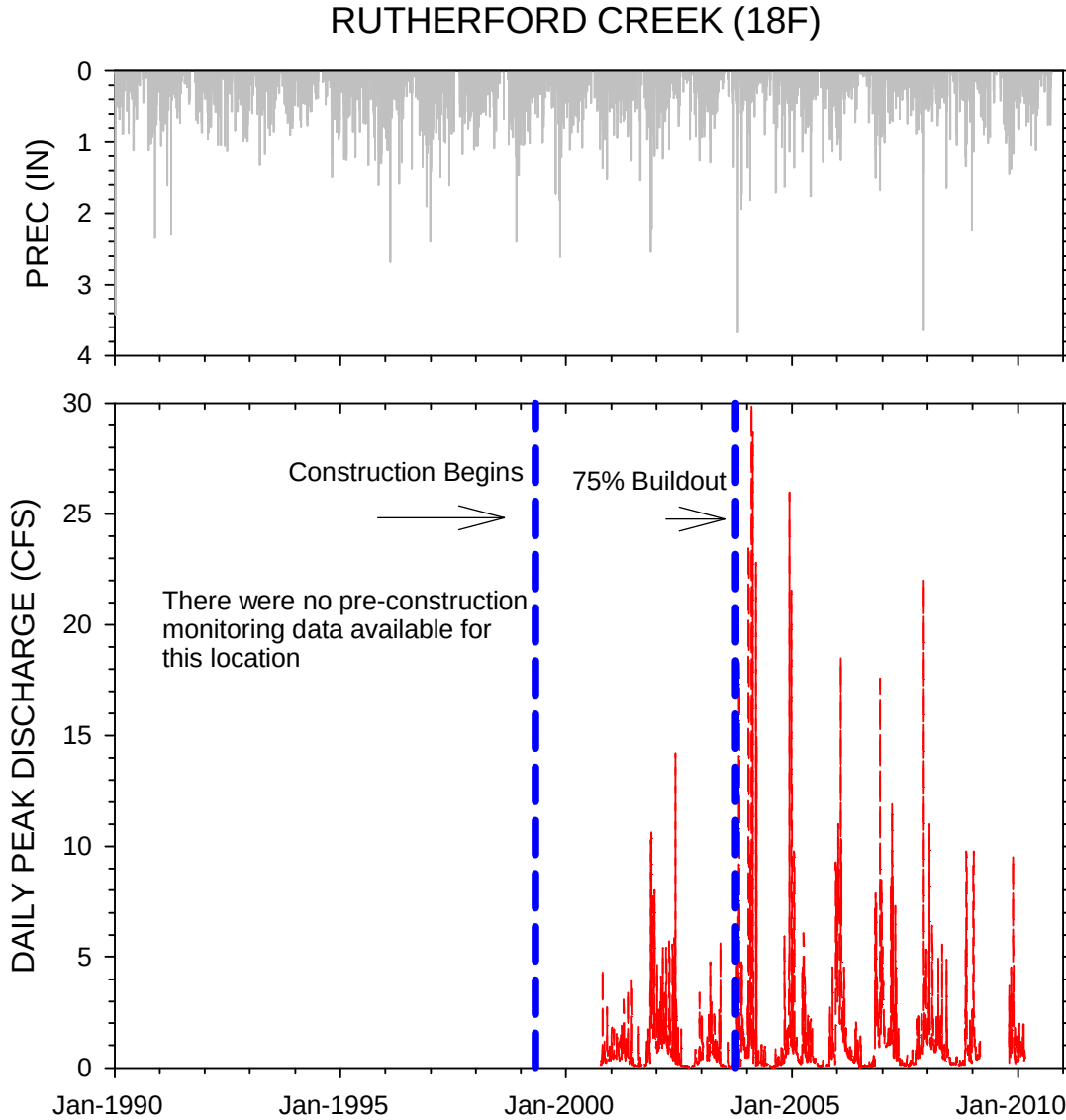


Figure A-11. Daily maximum discharge observed at the Rutherford Creek (18F) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Redmond Ridge basin.

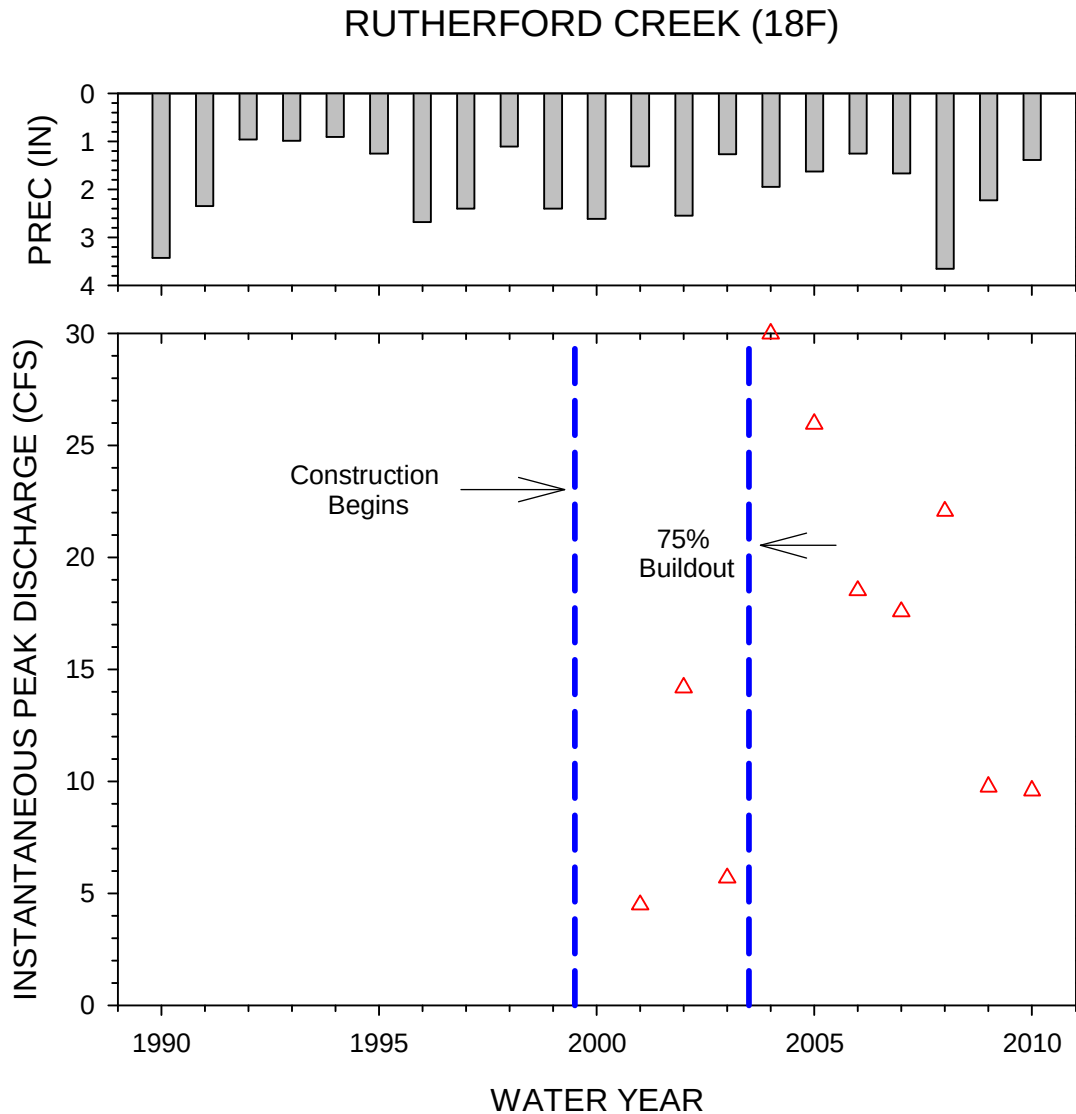


Figure A-12. Daily maximum discharge observed at the Rutherford Creek (18F) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Redmond Ridge basin.

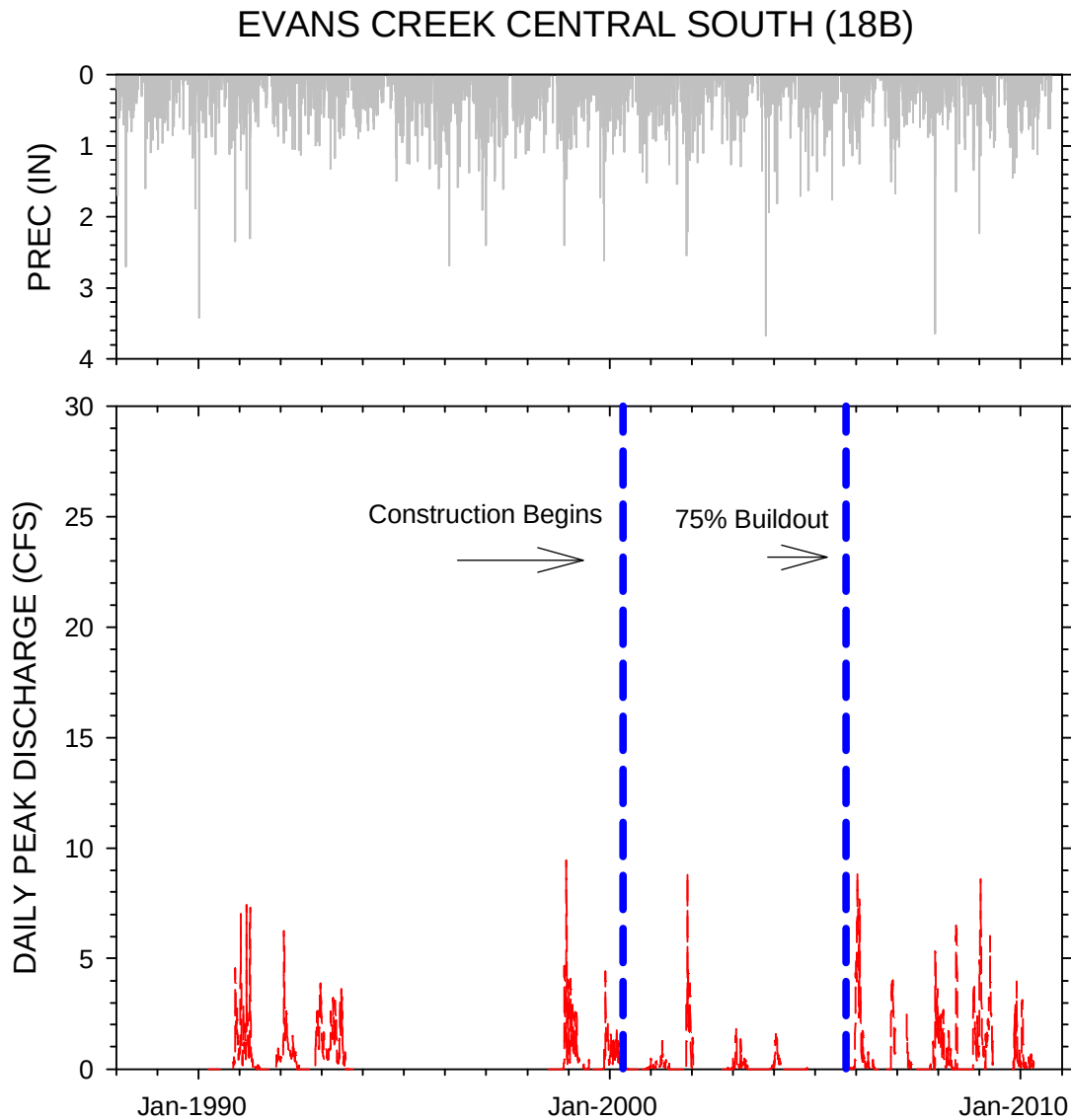


Figure A-13. Daily maximum discharge observed at the Evans Creek Central South (18B) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Redmond Ridge basin.

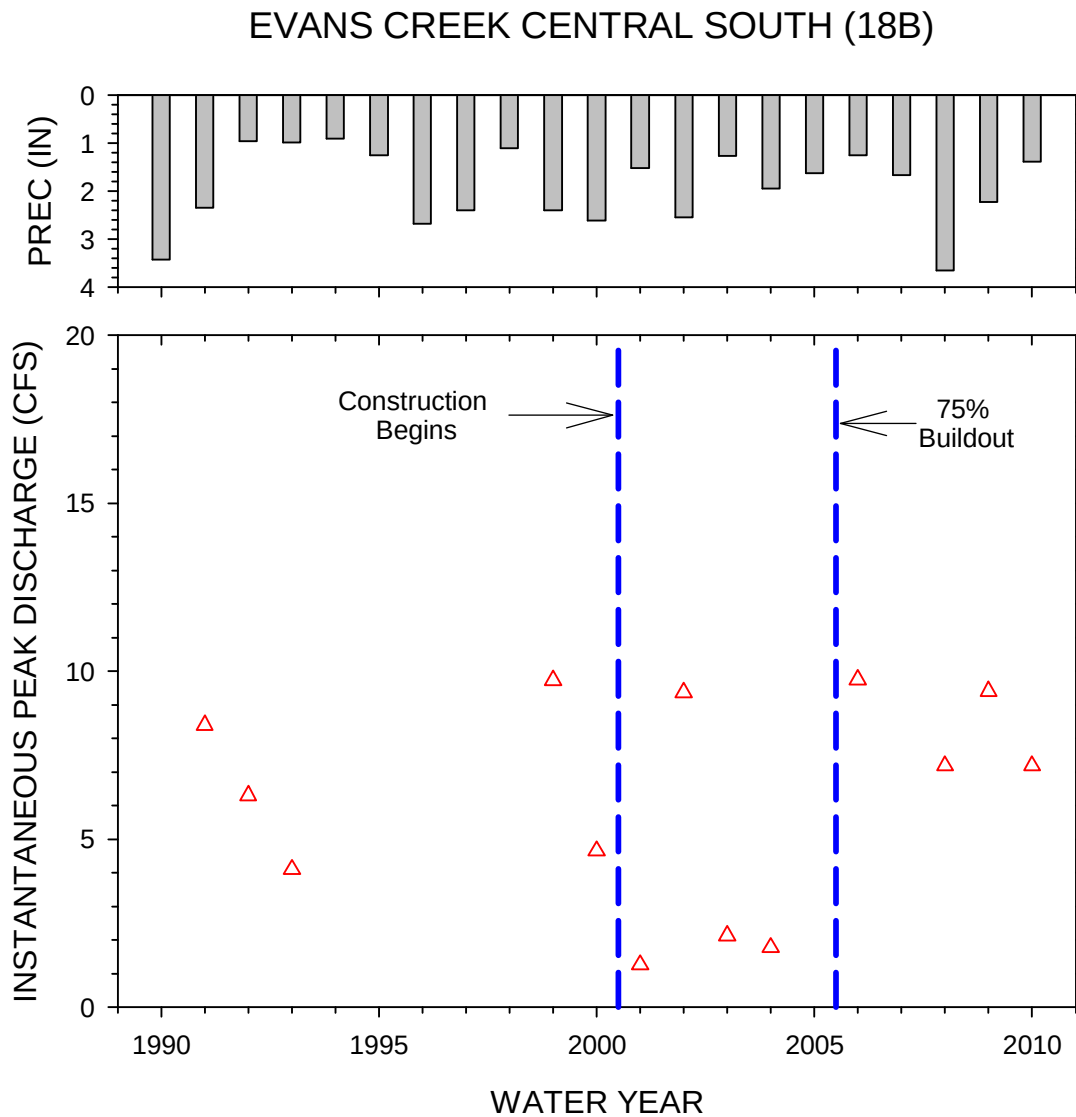


Figure A-14. Daily maximum discharge observed at the Rutherford Evans Creek Central South (18B) gage. Top panel shows the observed daily total precipitation during the gauging period. The vertical blue dashed lines indicate the initiation of construction and point of 75 percent buildout of the Redmond Ridge basin.

Appendix B. Flow flashiness

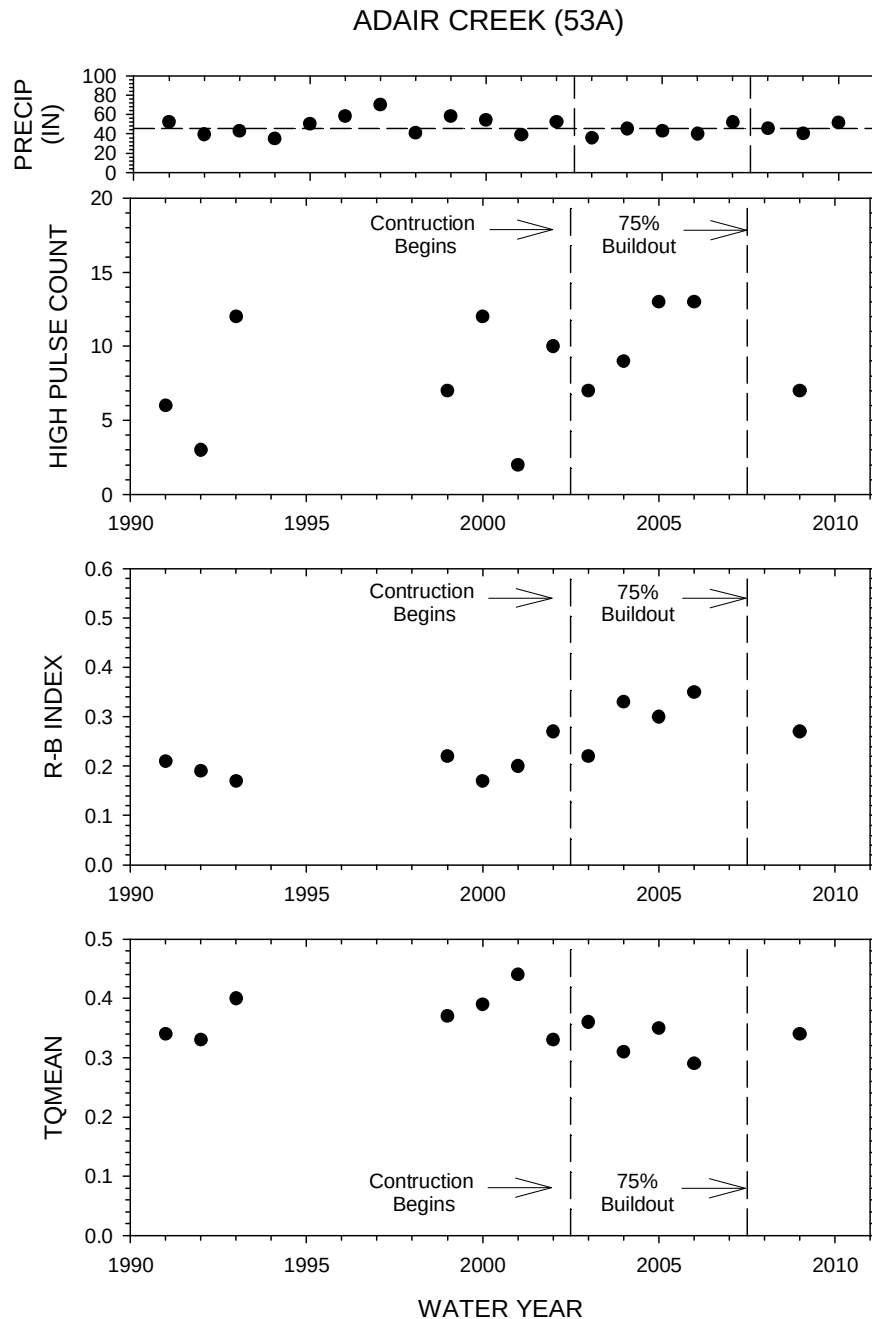


Figure B-1. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Adair Creek (53A) gage.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NE basin.

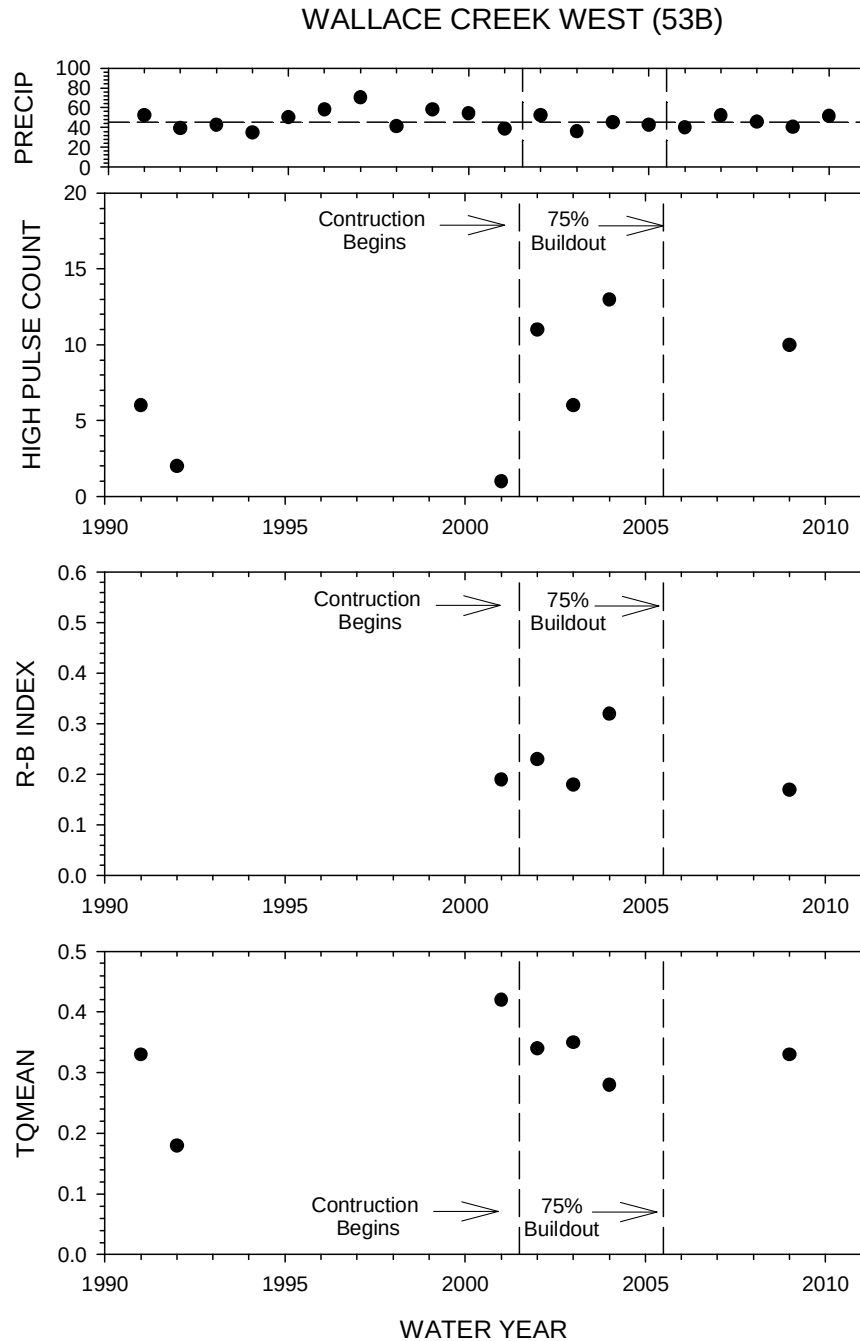


Figure B-2. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Wallace Creek West (53B) gage.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SE basin.

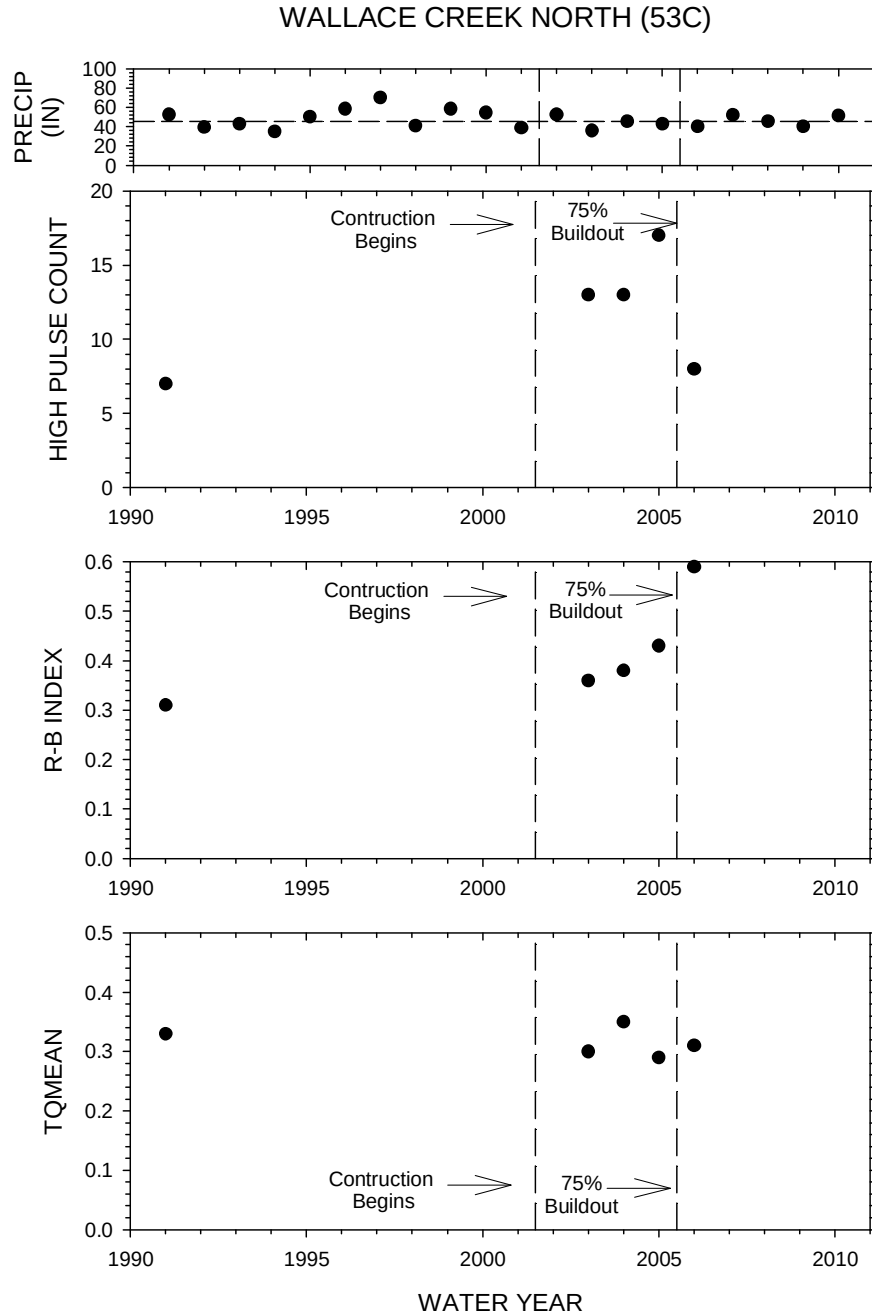


Figure B-3. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Wallace Creek North (53C) gage.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SE basin

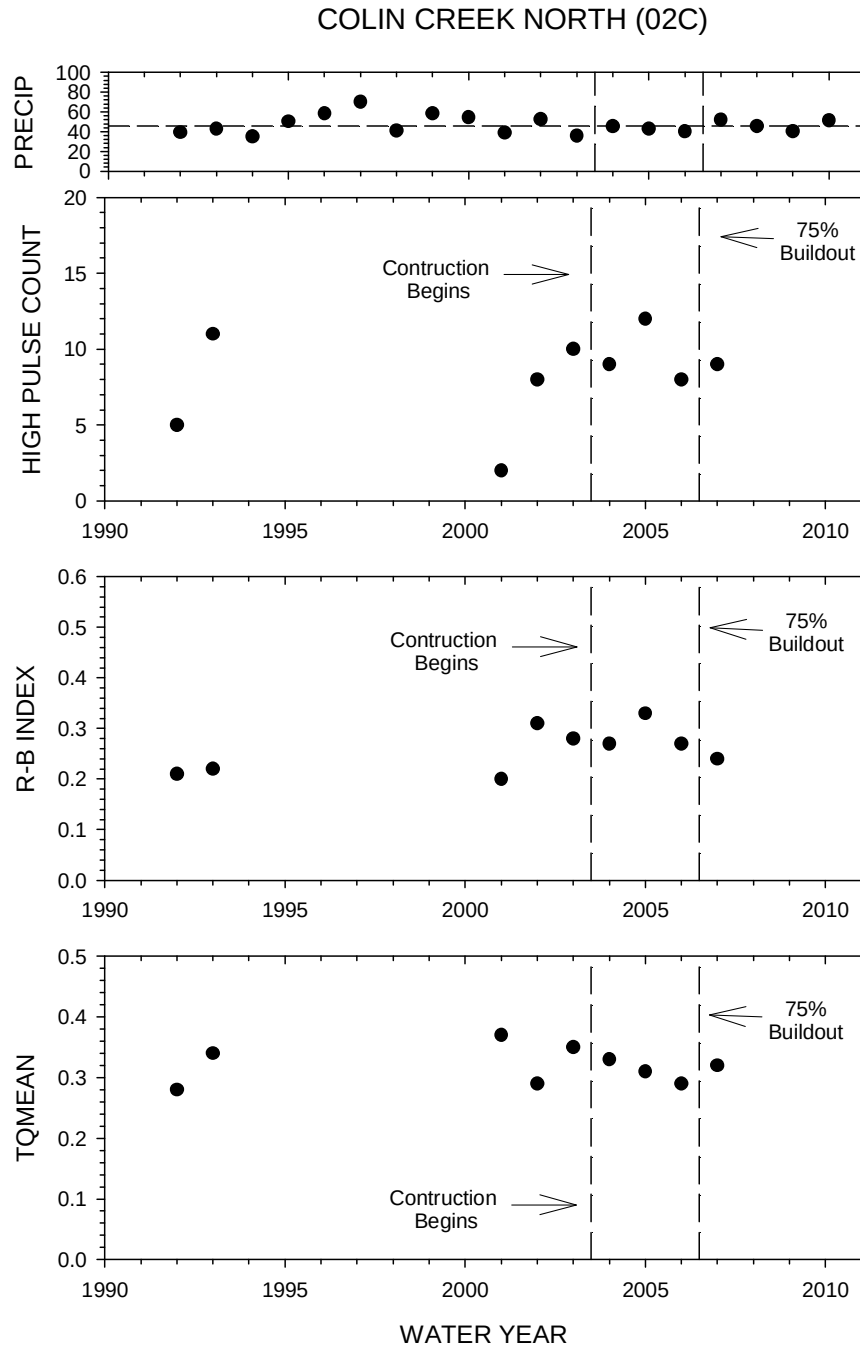


Figure B-4. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Colin Creek North (02C) gage.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NW basin.

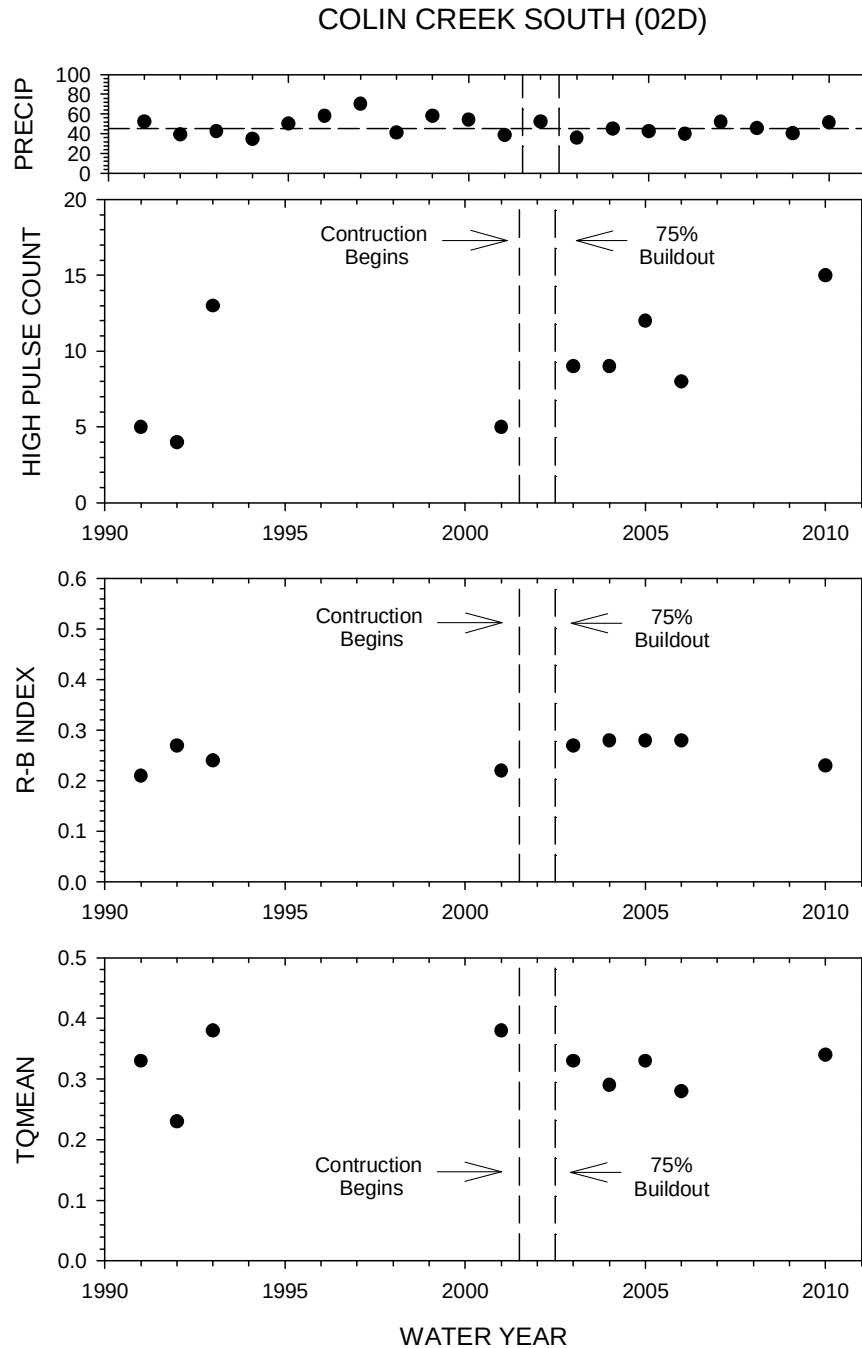


Figure B-5. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Colin Creek South (02D) gage.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SW basin.

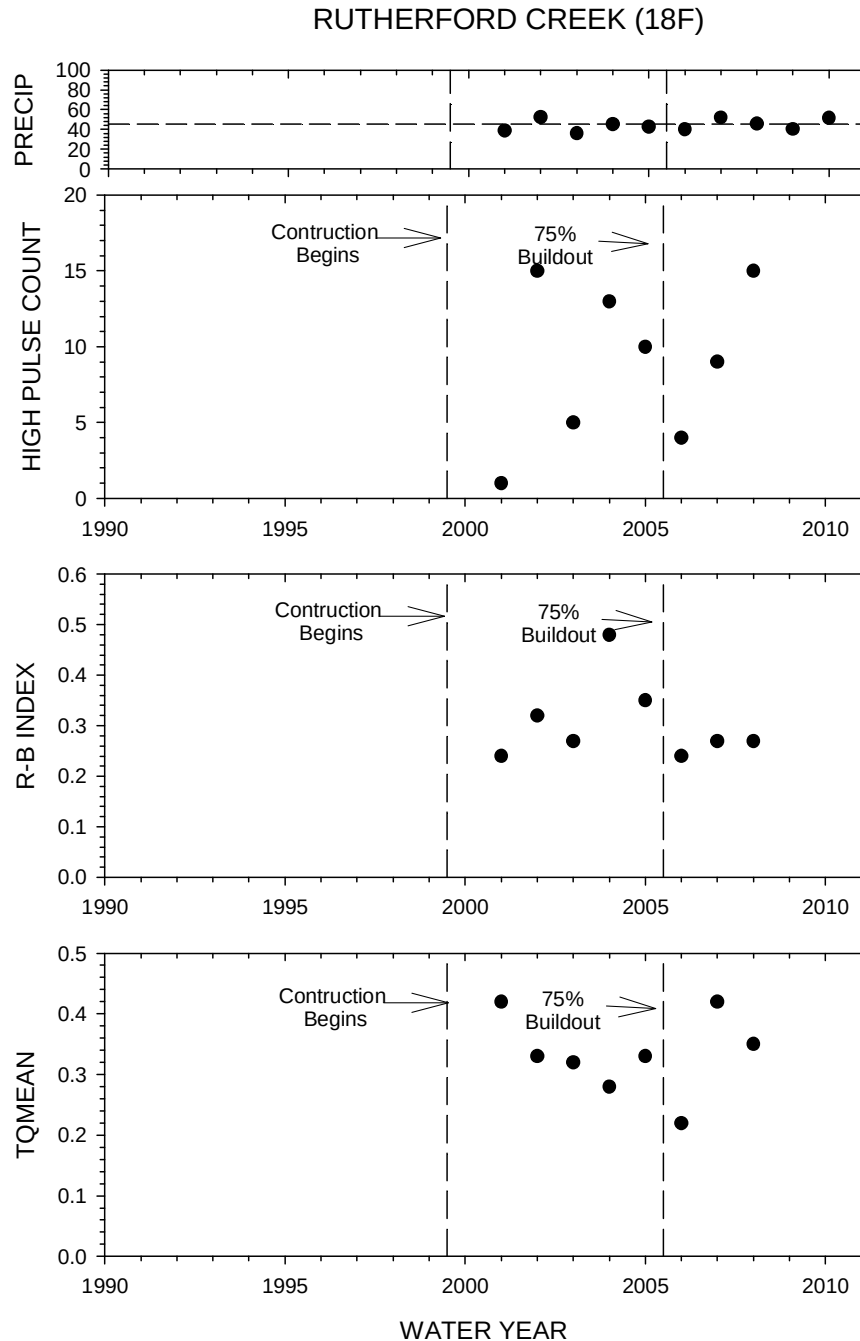


Figure B-6. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Rutherford Creek (18F) gage.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Redmond Ridge basin.

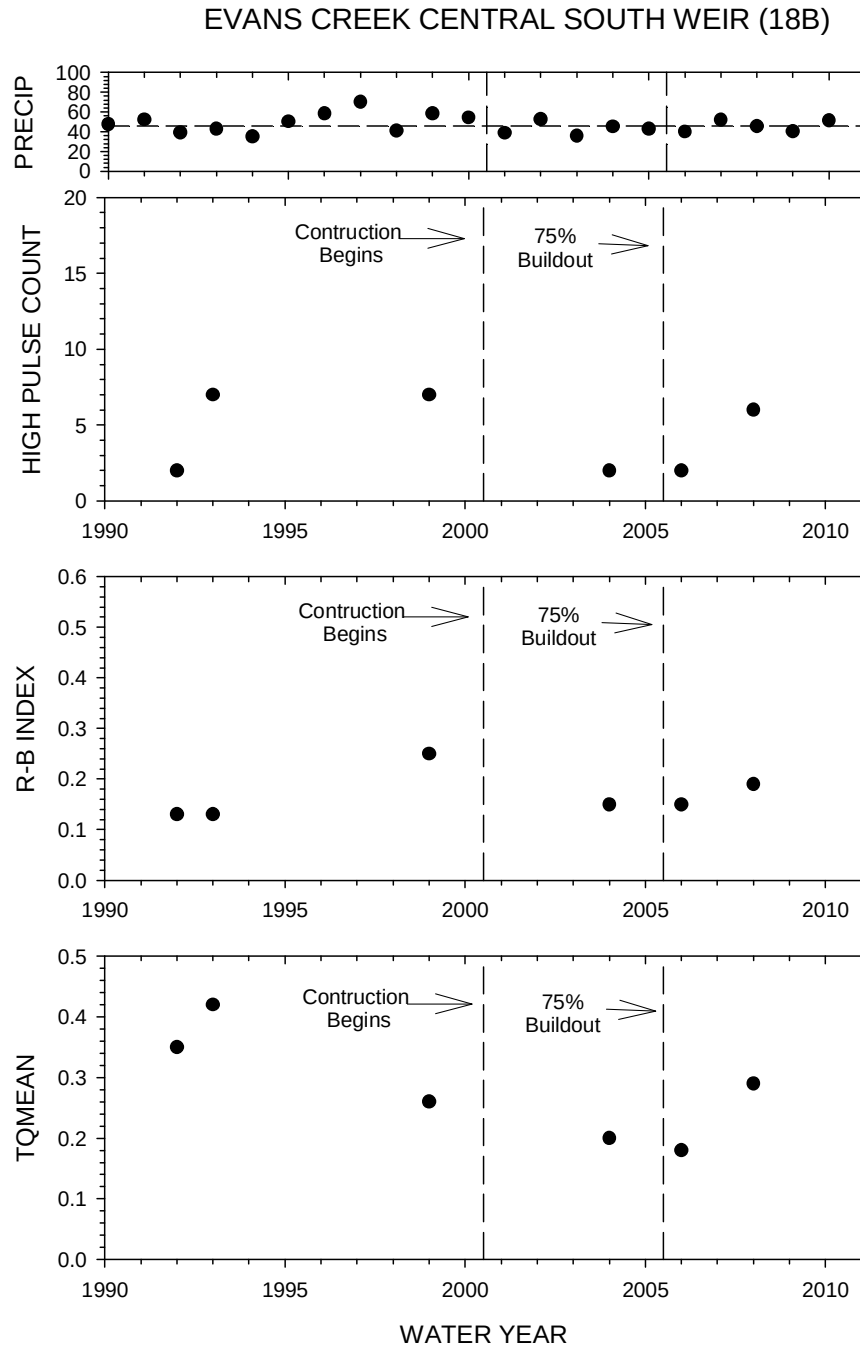


Figure B-7. Flow flashiness metrics High Pulse Count, R-B Index, and TQmean calculated from complete observed daily flow data collected at the Evans Creek Central South (18B) gage.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Redmond Ridge basin.

Appendix C. Base flow

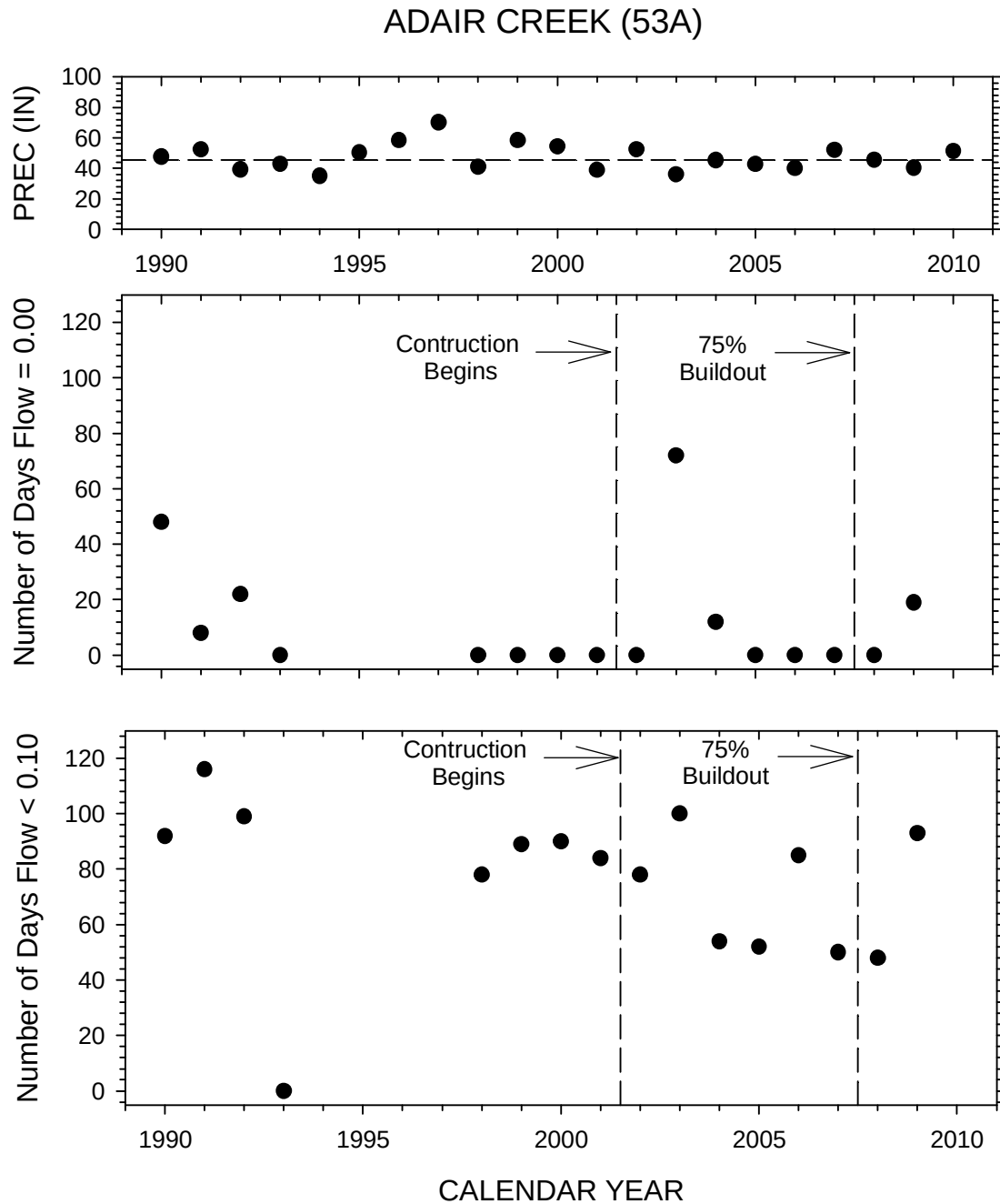


Figure C-1. Number of days each summer (July-October) that Adair Creek (53A) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NE basin.

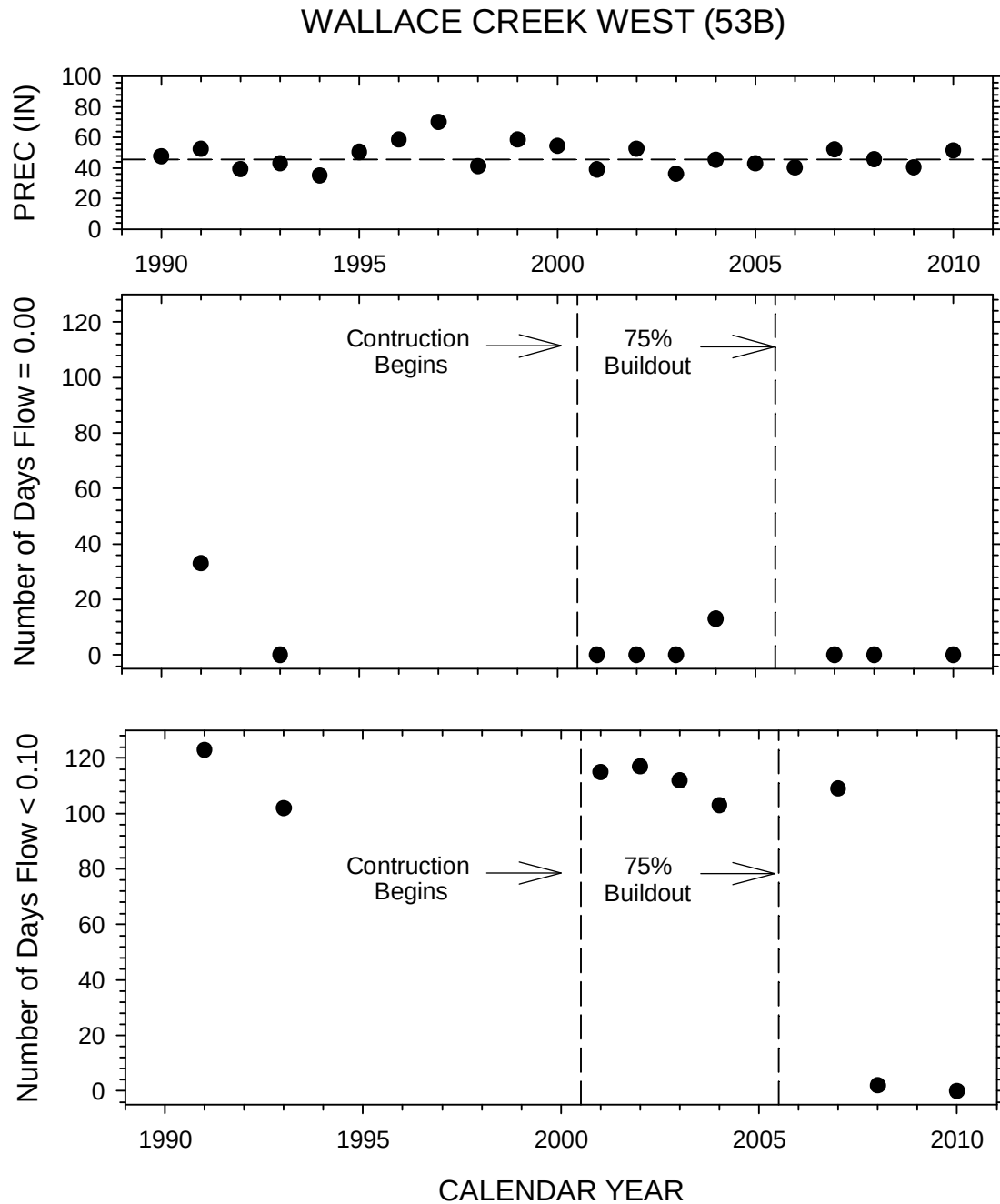


Figure C-2. Number of days each summer (July-October) that Wallace Creek West (53B) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SE basin.

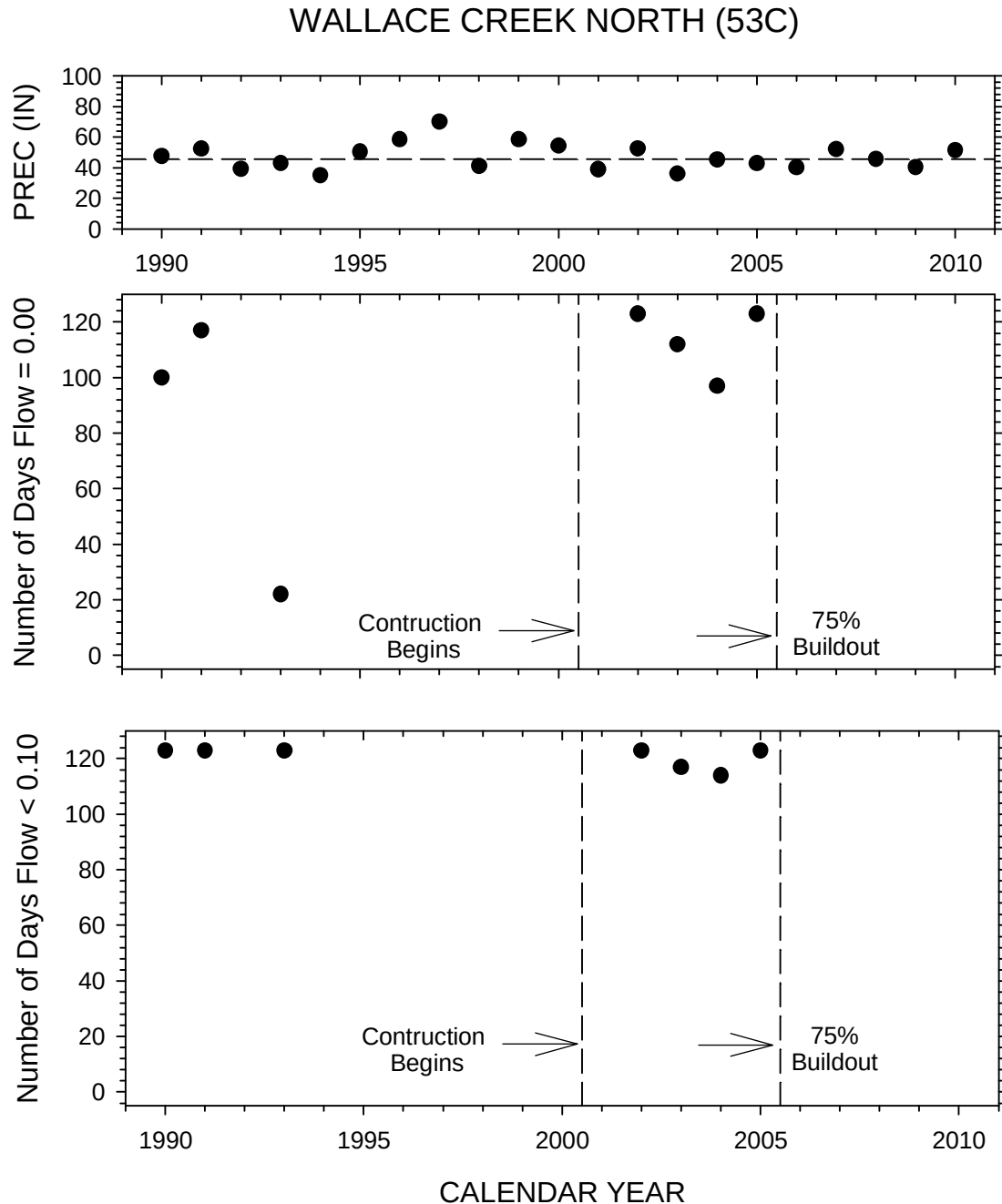


Figure C-3. Number of days each summer (July-October) that Wallace Creek North (53F) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SE basin.

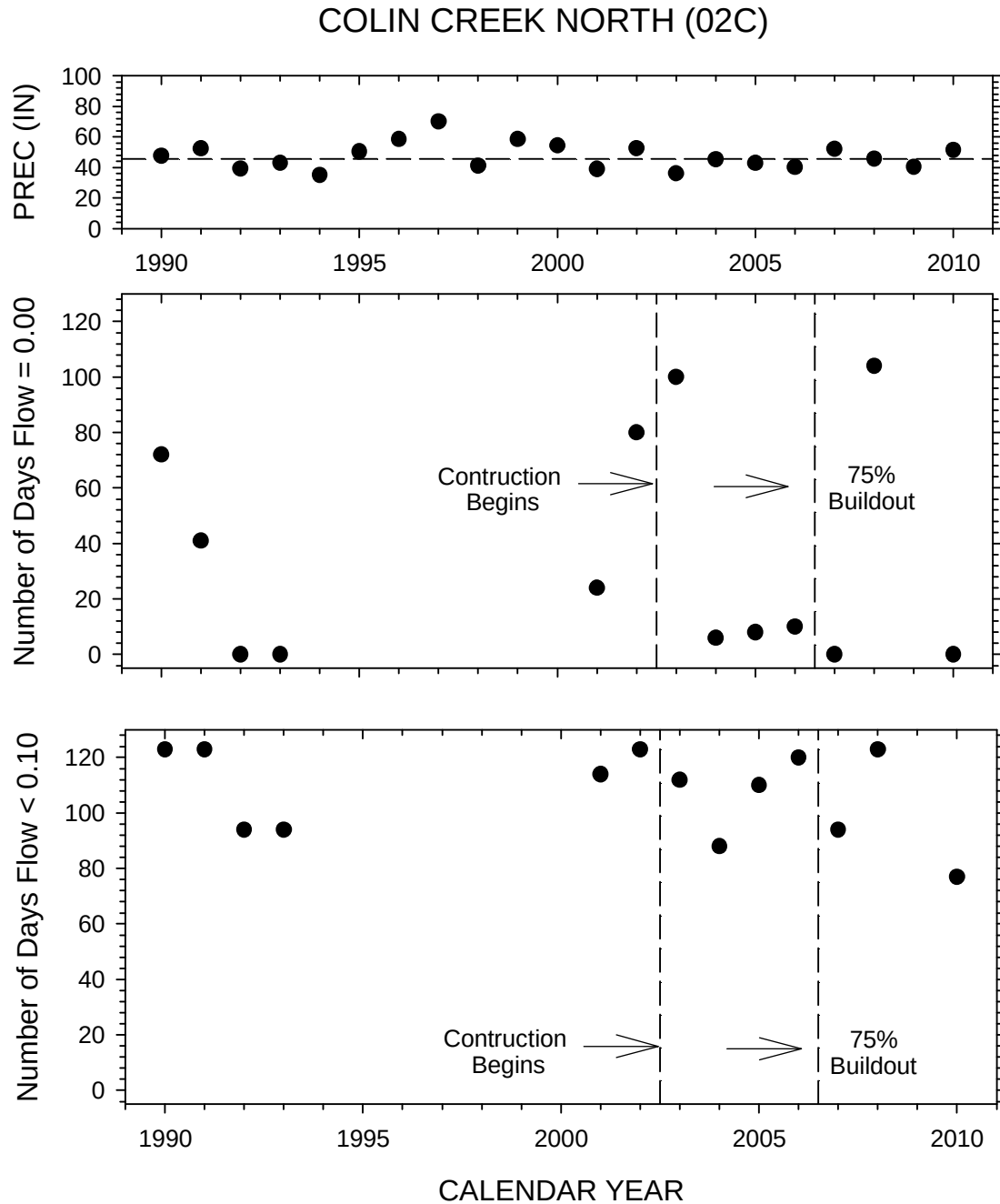


Figure C-4. Number of days each summer (July-October) that Colin Creek North (02C) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy NW basin.

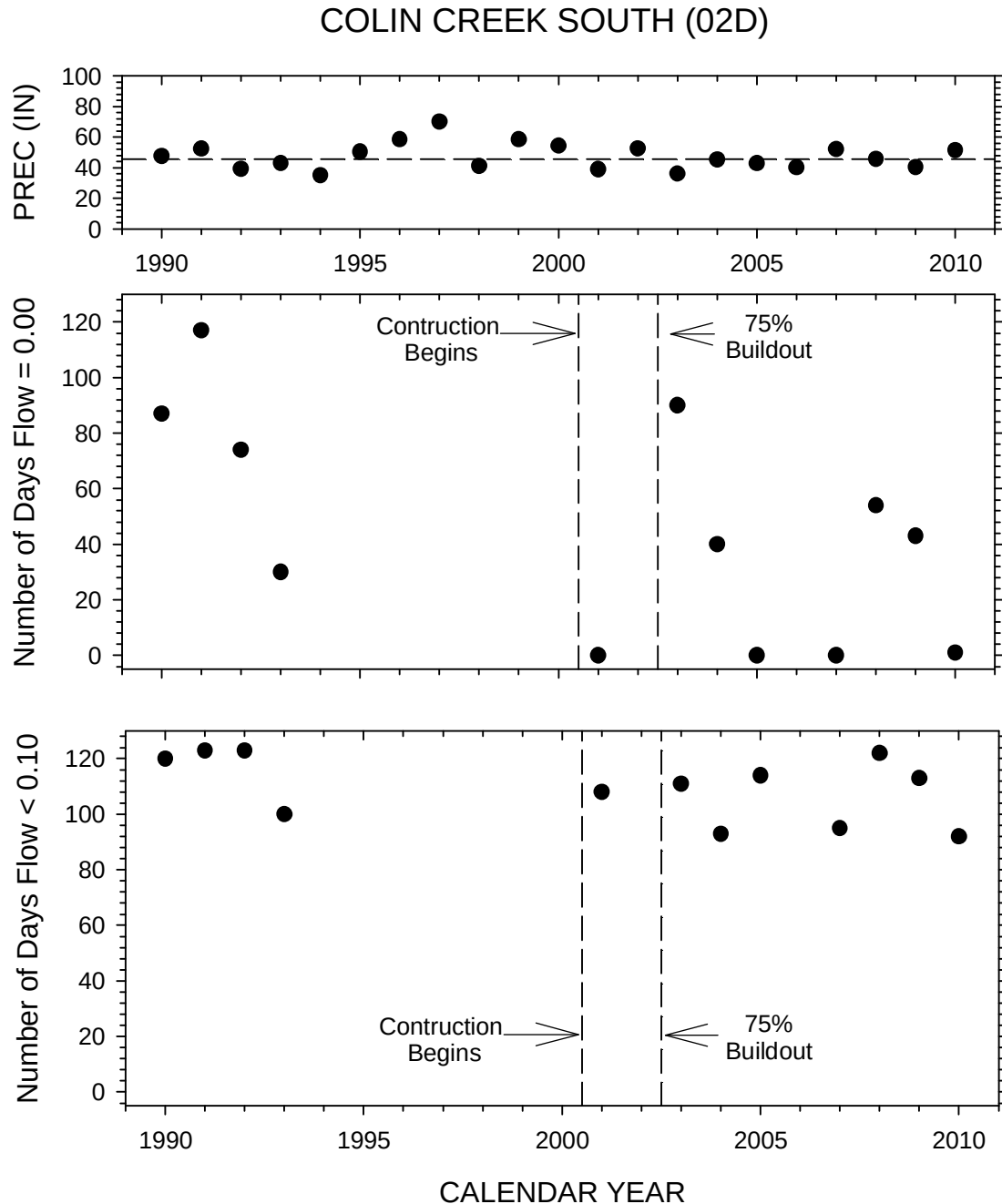


Figure C-5. Number of days each summer (July-October) that Colin Creek South (02D) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Trilogy SW basin.

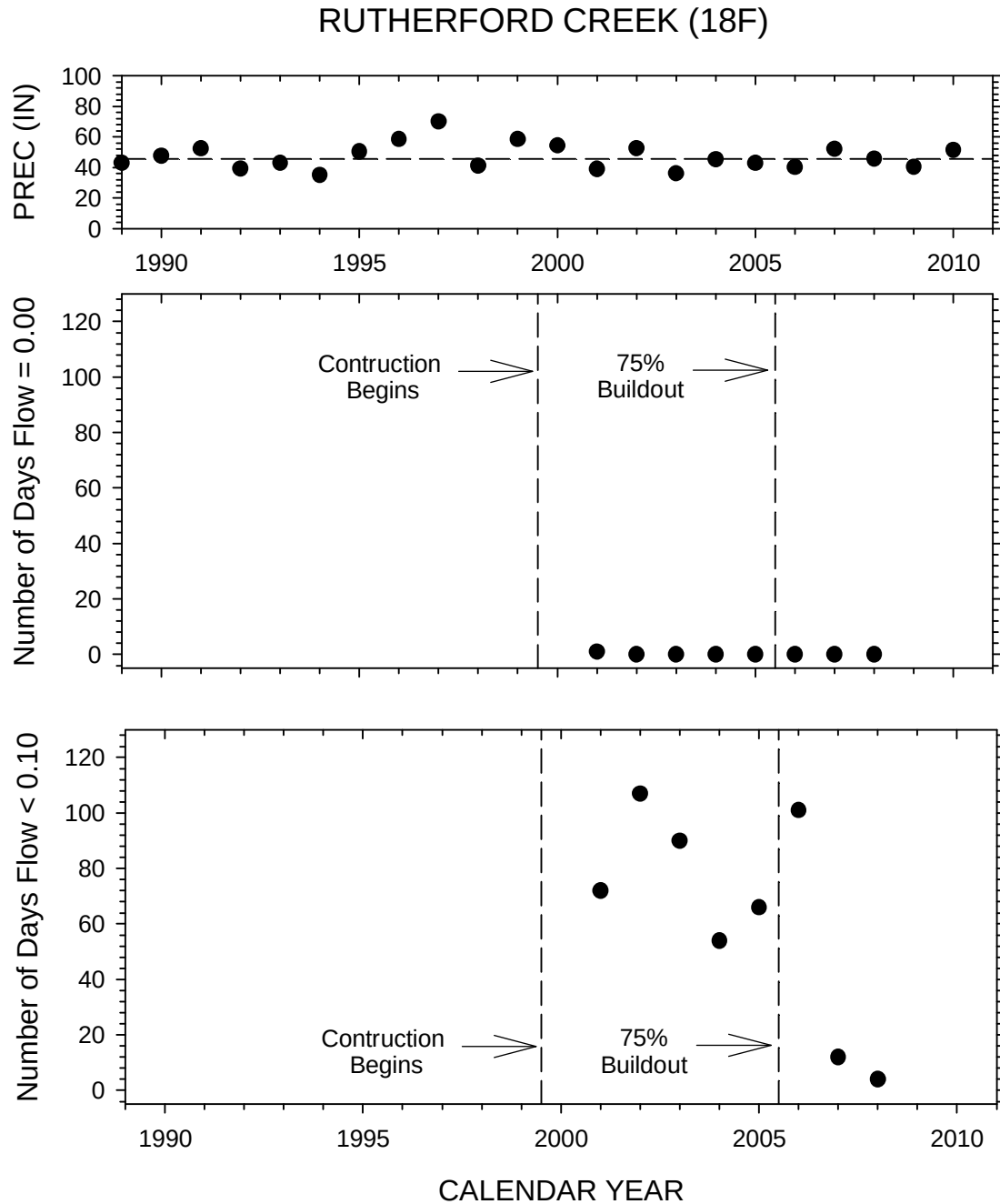


Figure C-6. Number of days each summer (July-October) that Rutherford Creek (18F) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs.

Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Redmond Ridge basin.

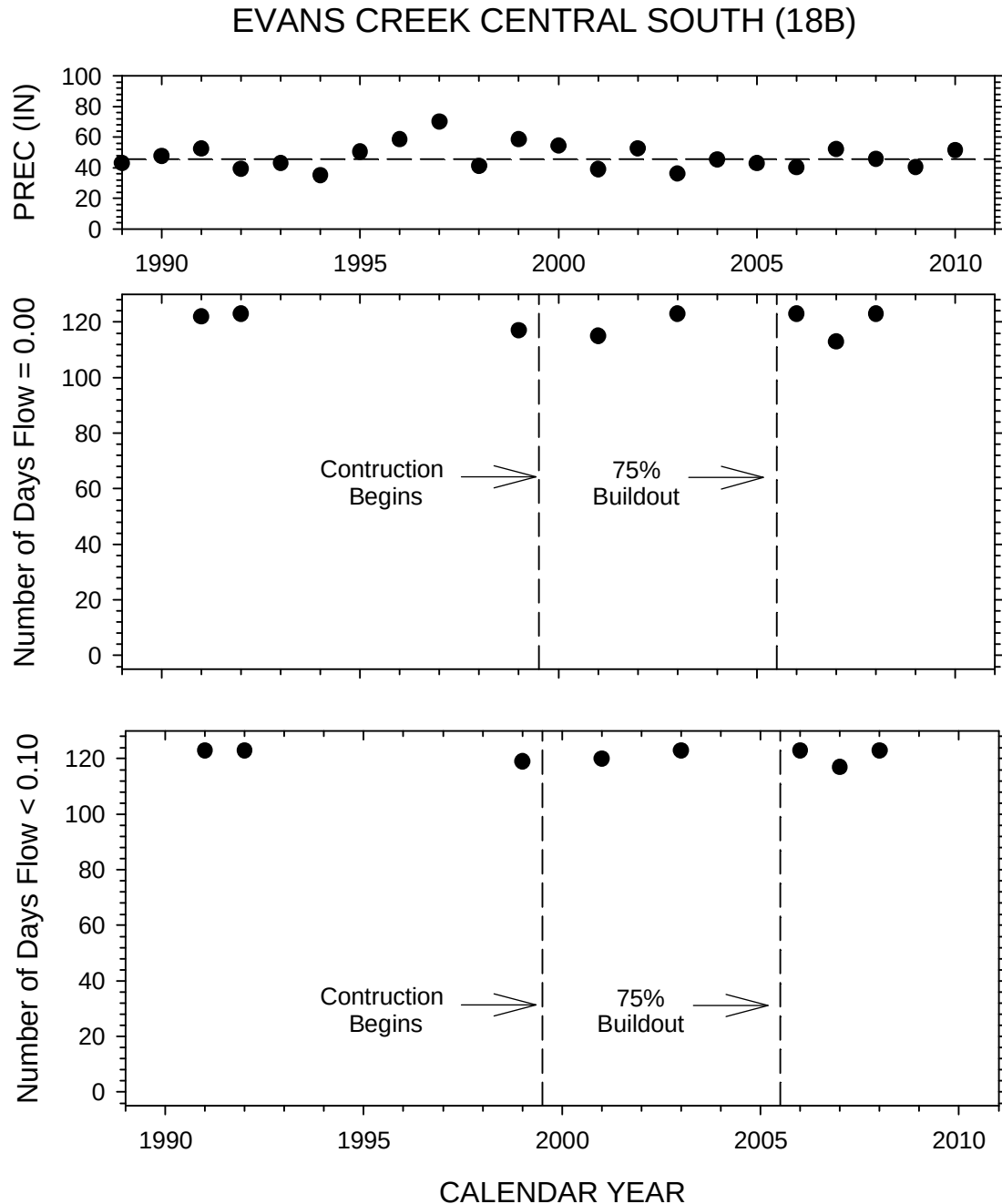


Figure C-7. Number of days each summer (July-October) that Evans Creek Central South (18B) was dry (Flow = 0.00) and the number of days over the same period that flow was less than 0.1 cfs. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the Redmond Ridge basin.

Appendix D. Wetland Water Levels

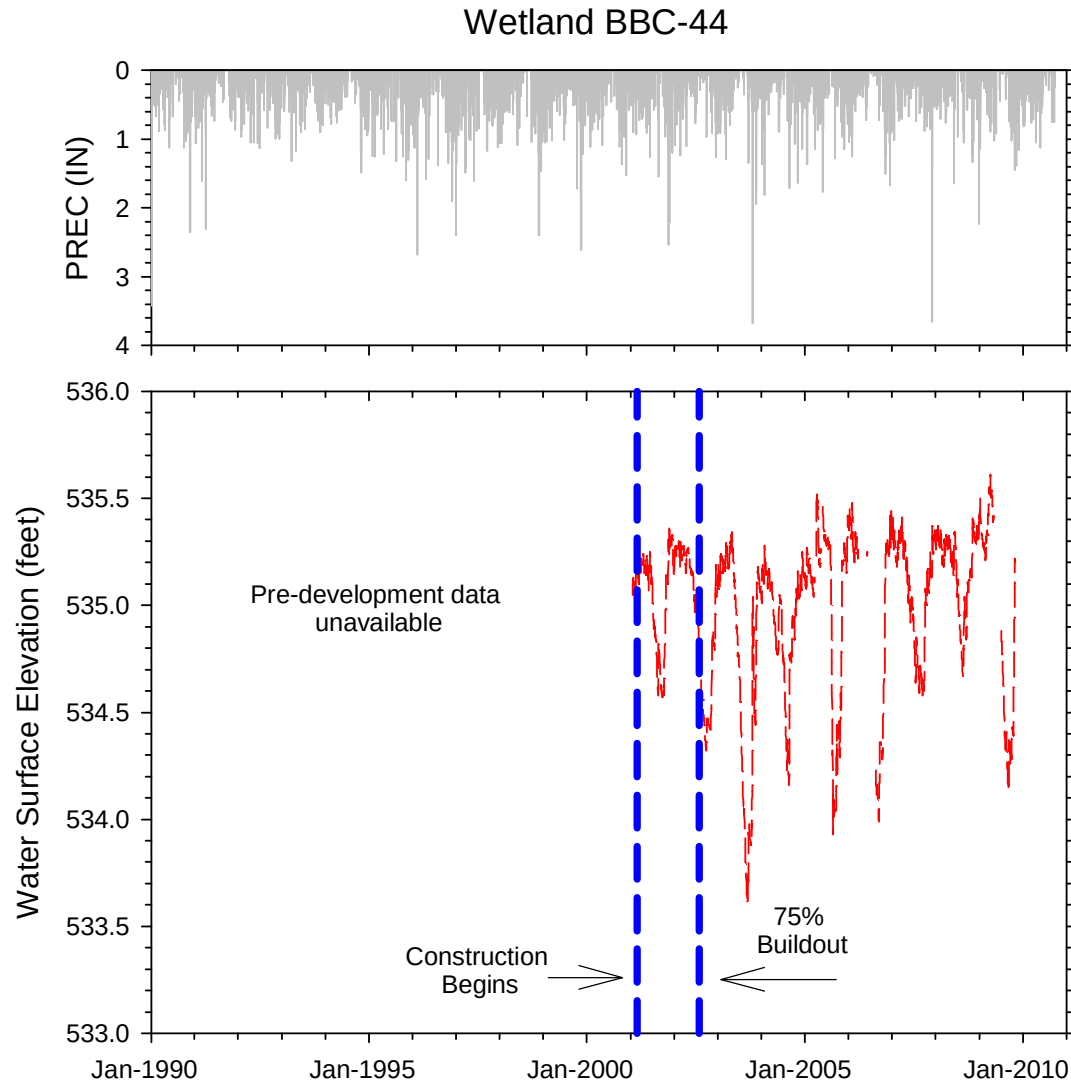


Figure D-1. Observations of wetland water levels in Trilogy wetland BBC-44.

No pre-development baseline data are available for comparison. Construction monitoring elevations are daily average elevations based on continuous stage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

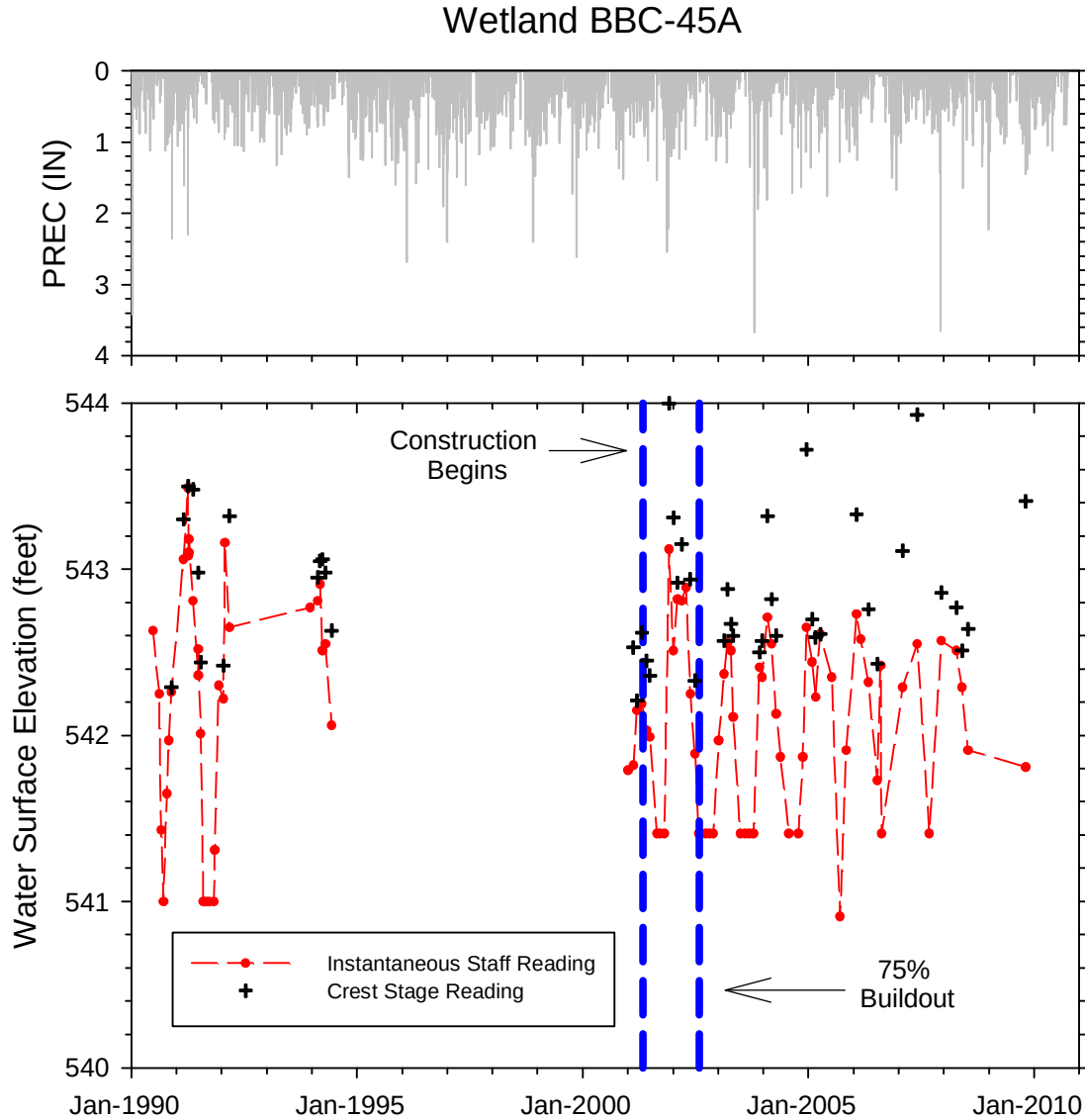


Figure D-2. Observations of wetland water levels in Trilogy wetland BBC-45A. Pre-development baseline and construction phase monitoring based on instantaneous staff and crest stage gage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Wetland BBC-26

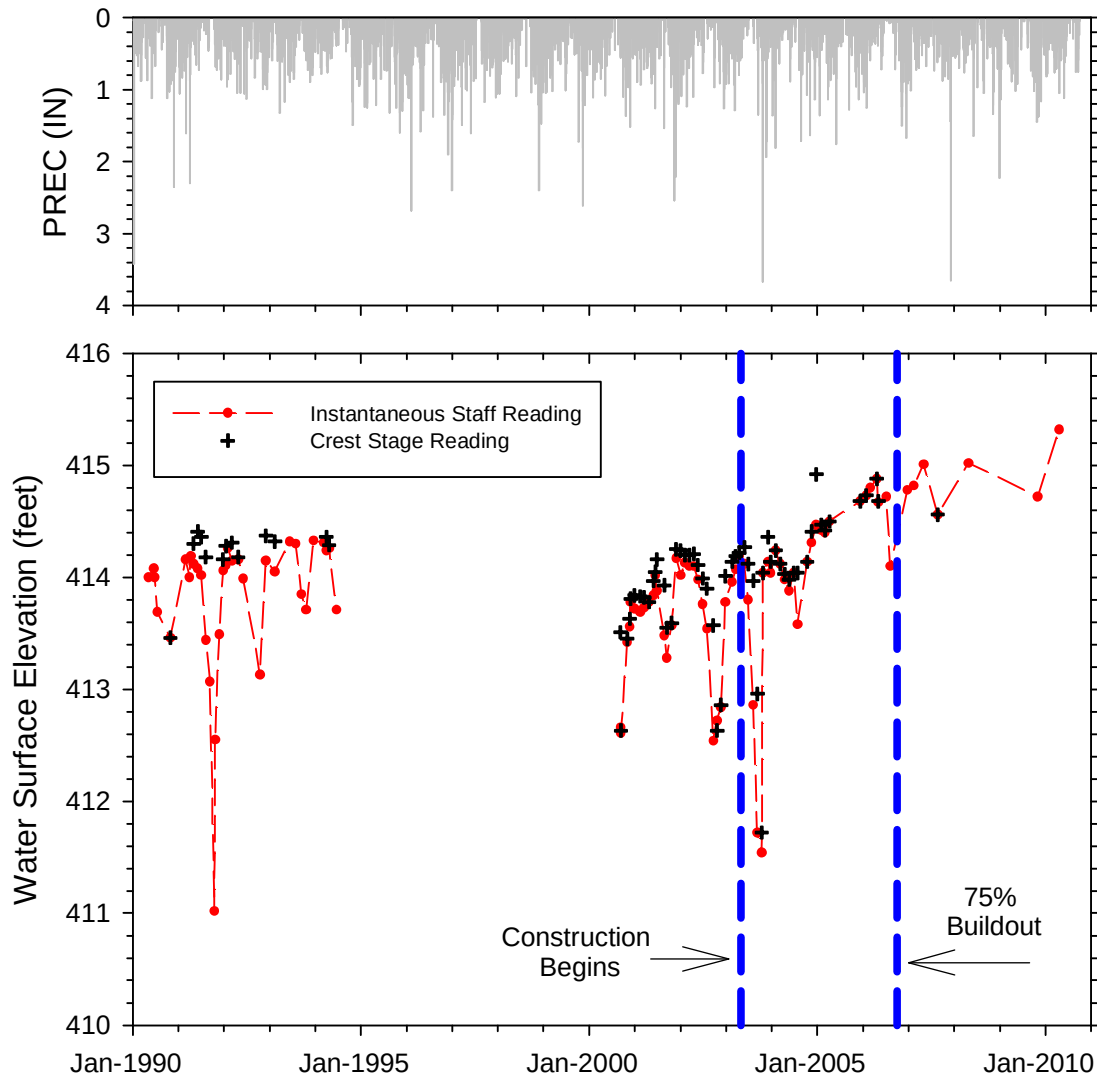


Figure D-3. Observations of wetland water levels in Trilogy wetland BBC-26.

Pre-development baseline and construction phase monitoring based on instantaneous staff and crest stage gage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

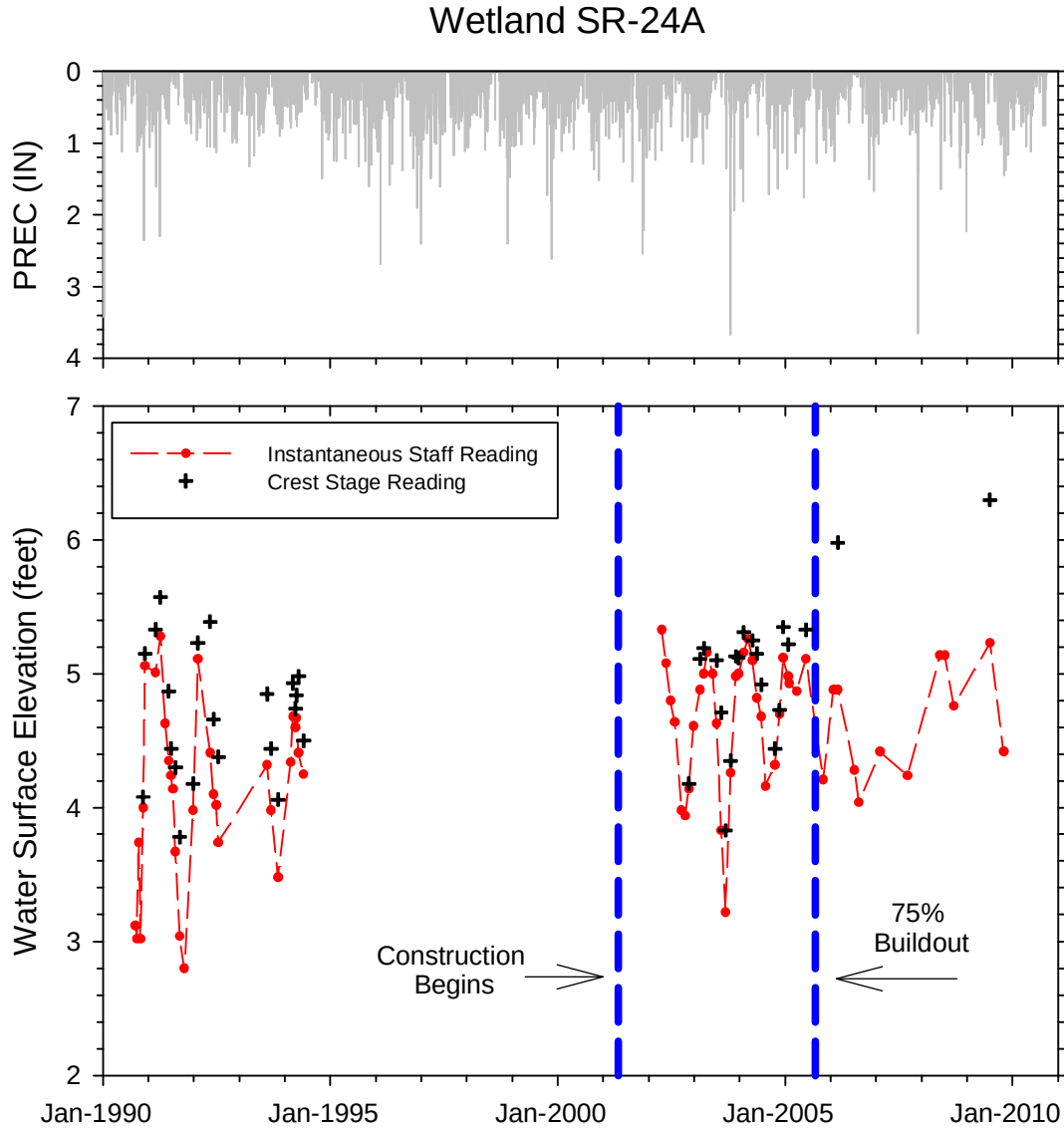


Figure D-4. Observations of wetland water levels in Trilogy wetland SR-24A.

Pre-development baseline and construction phase monitoring based on instantaneous staff and crest stage gage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

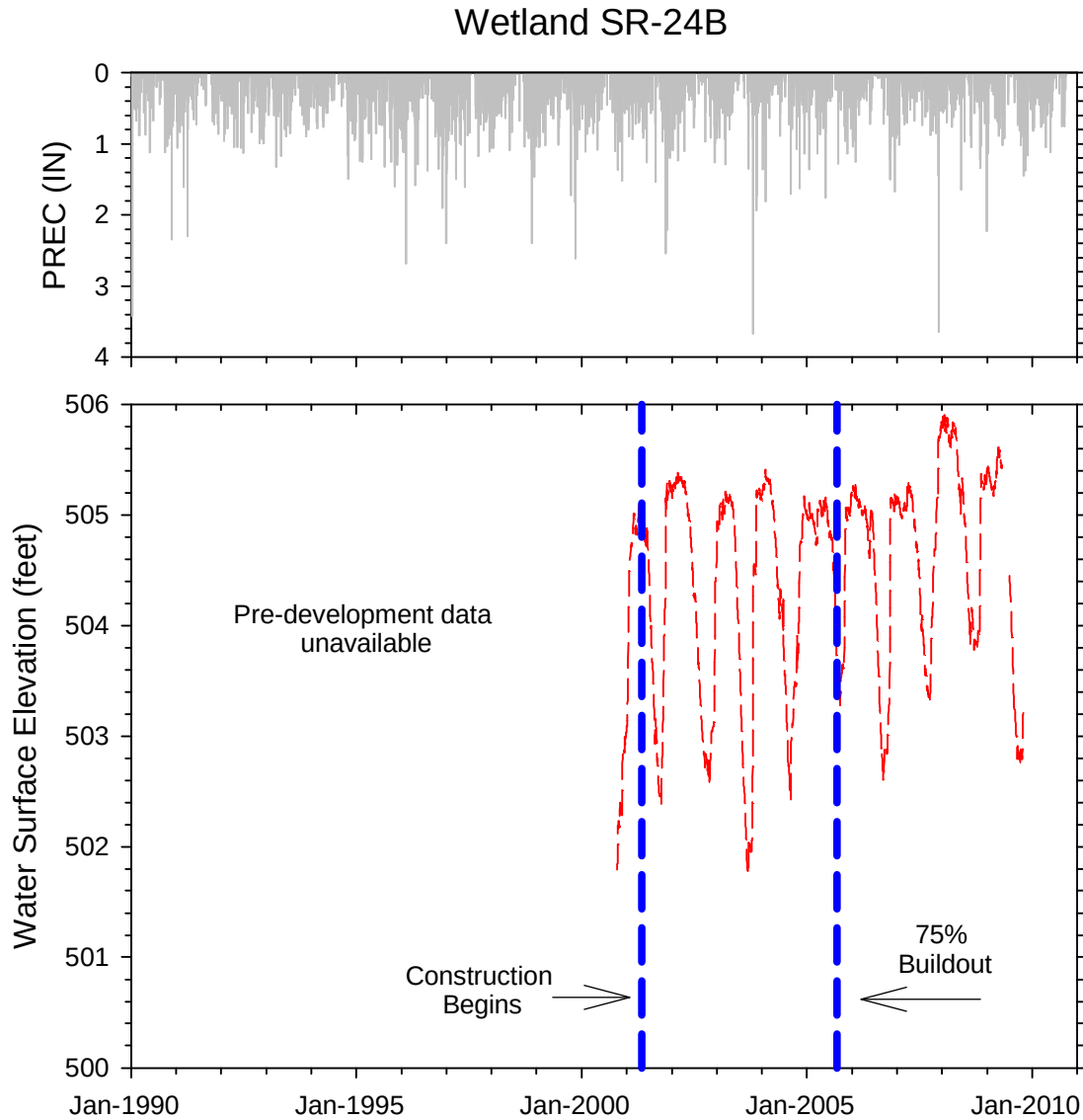


Figure D-5. Observations of wetland water levels in Trilogy wetland SR-24B.

No pre-development baseline data are available for comparison. Construction monitoring elevations are daily average elevations based on continuous stage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

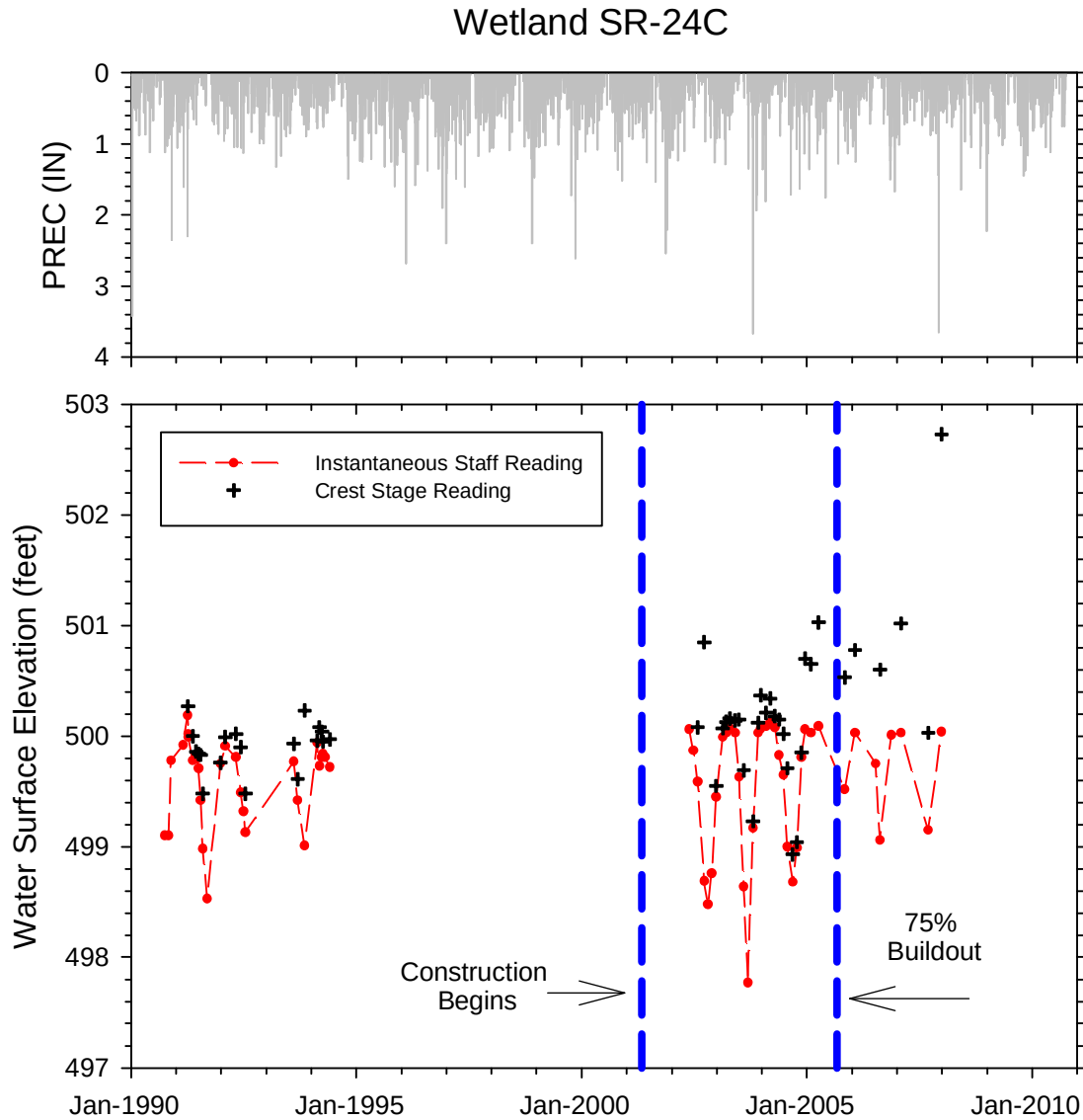


Figure D-6. Observations of wetland water levels in Trilogy wetland SR-24C. Pre-development baseline and construction phase monitoring based on instantaneous staff and crest stage gage readings. Top panel shows daily precipitation totals. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Appendix E. Wetland June 30, spring/summer median and winter median water levels

Wetland BBC-44

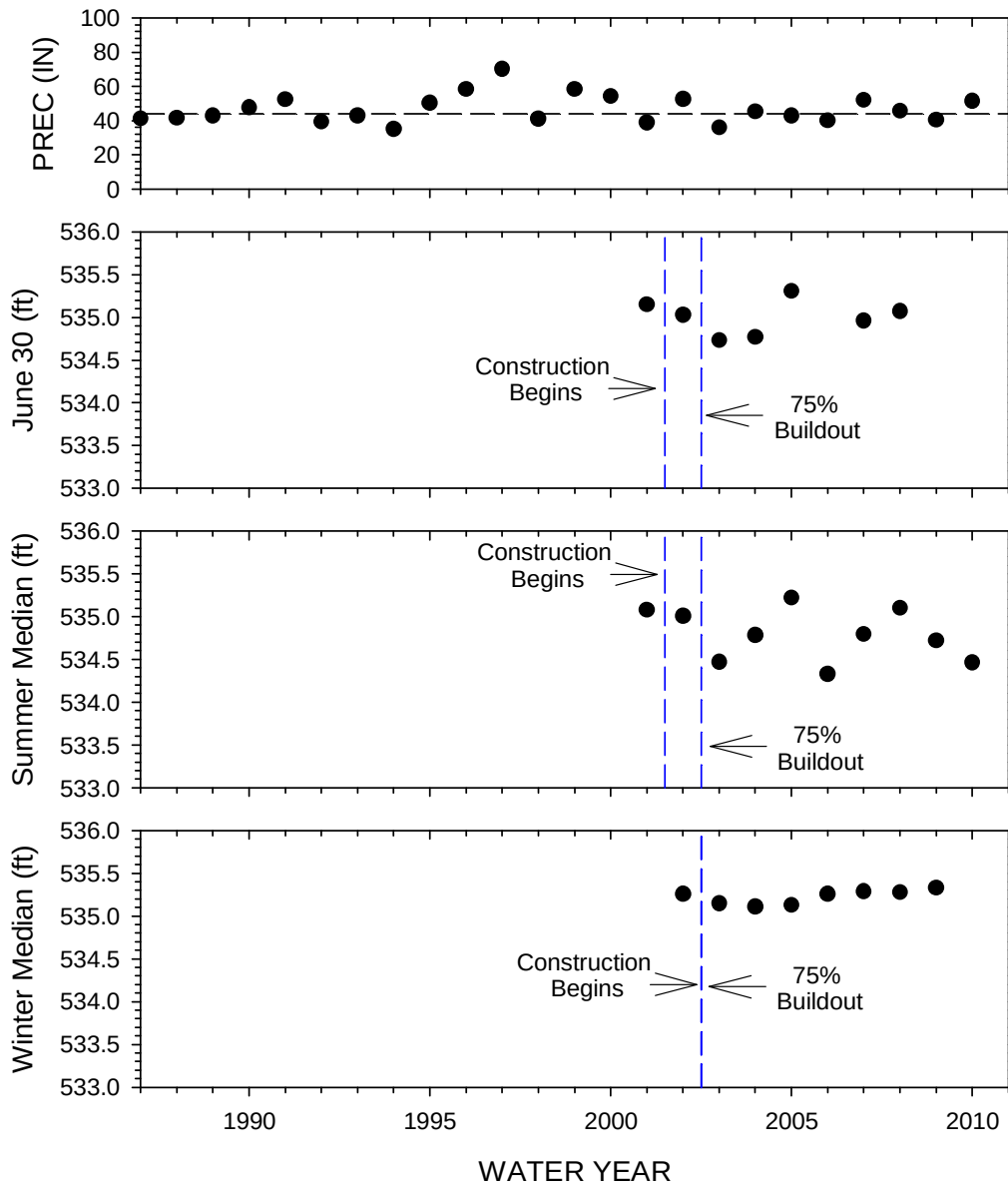


Figure E-1. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland BBC-44.

No Pre-development baseline data were available for comparison. Construction monitoring estimates are based on daily average elevations from continuous stage readings. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2002. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Wetland BBC-45A

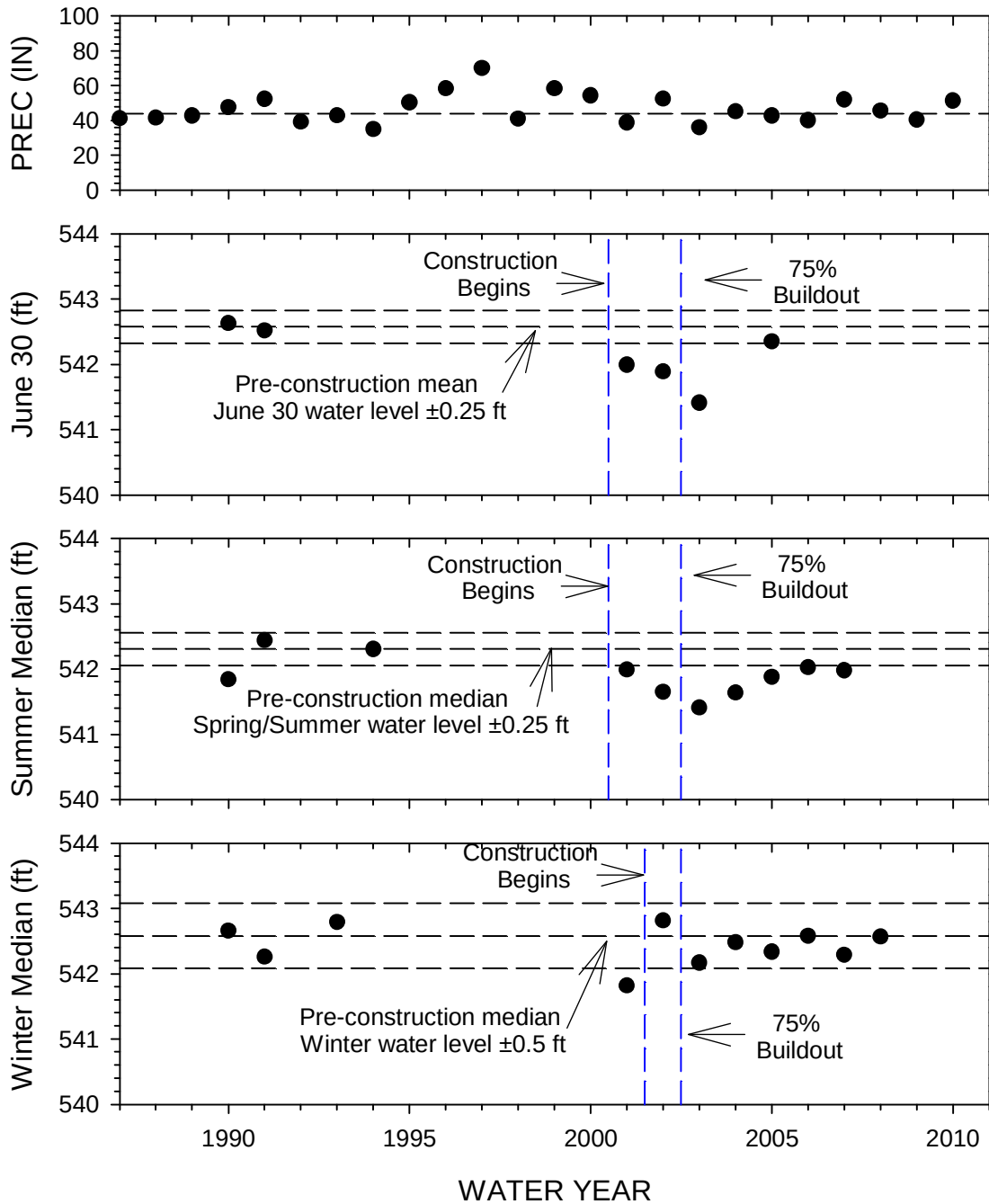


Figure E-2. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland BBC-45A.

Estimates are based on instantaneous staff plate readings conducted approximately monthly. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2001. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Wetland BBC-26

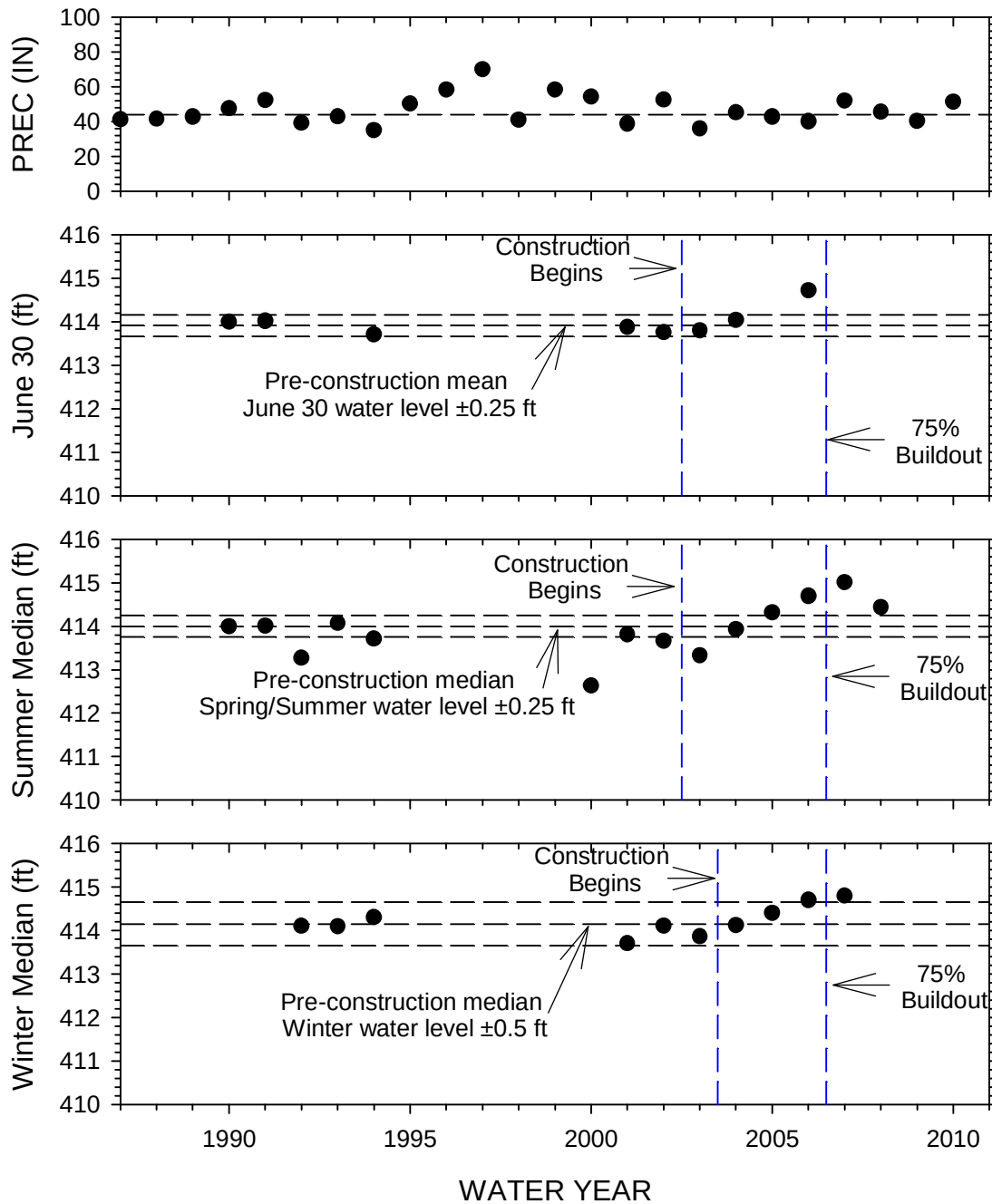


Figure E-3. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland BBC-26.

Estimates are based on instantaneous staff plate readings conducted approximately monthly. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2003. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this page.

Wetland SR-24A

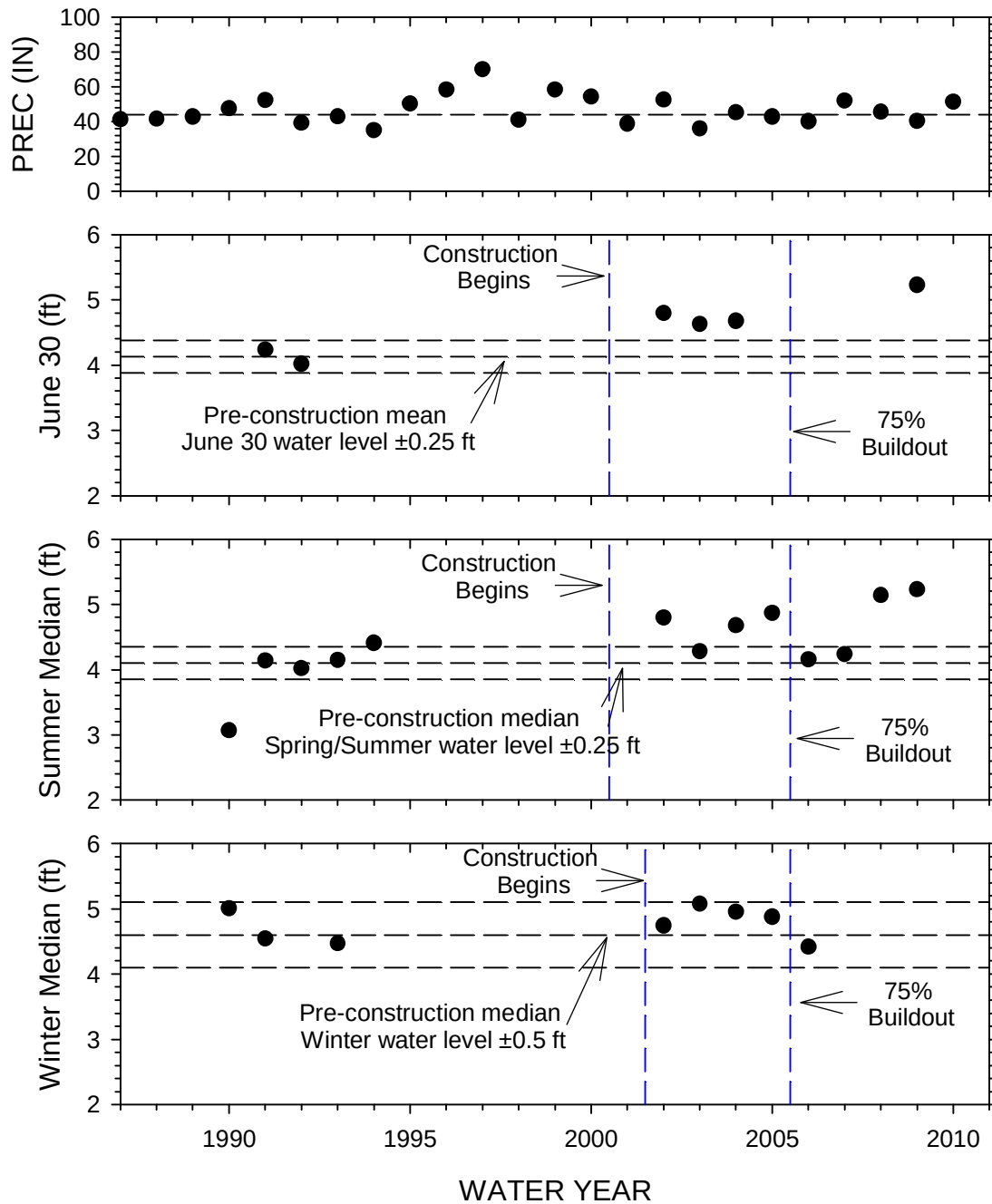


Figure E-4. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland SR-24A.

Estimates are based on instantaneous staff plate readings conducted approximately monthly. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2001. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this page.

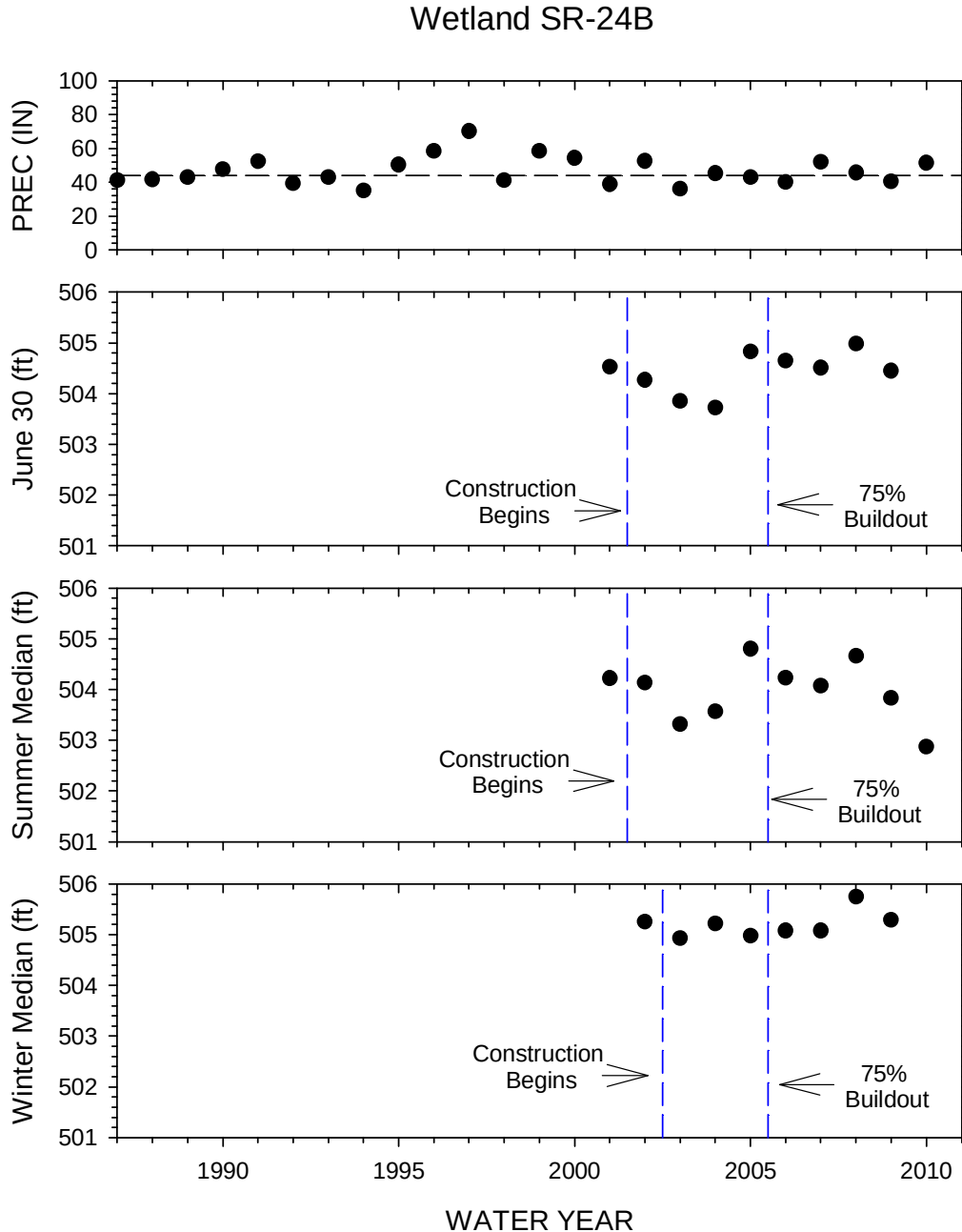


Figure E-5. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland SR-24B.

No Pre-development baseline data were available for comparison. Construction monitoring estimates are based on daily average elevations from continuous stage readings. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2002. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Wetland SR-24C

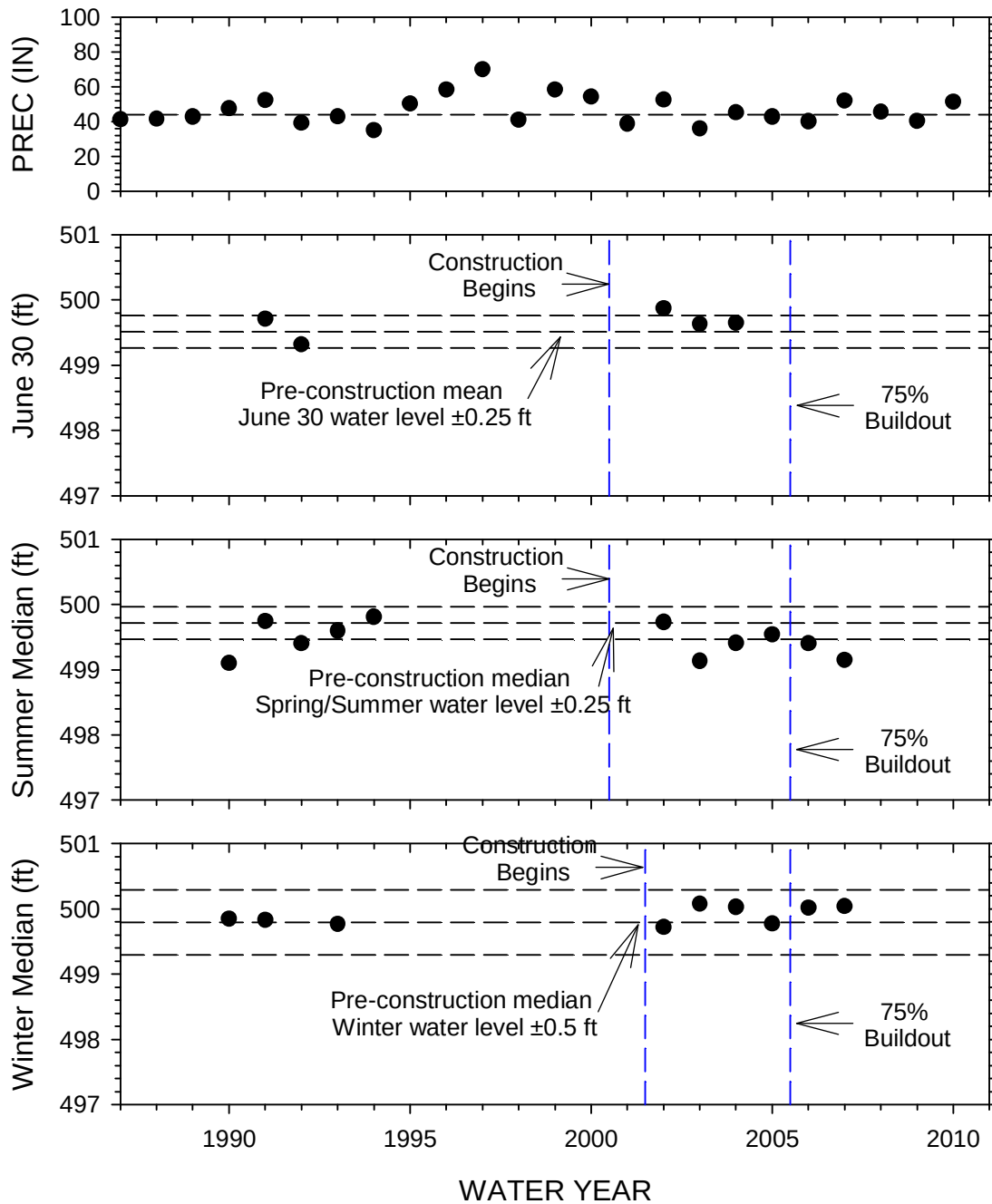


Figure E-6. Estimates of June 30, spring/summer median and winter median wetland water levels in Trilogy wetland SR-24C.

Estimates are based on instantaneous staff plate readings conducted approximately monthly. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2001. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this page.

Wetland EC-3

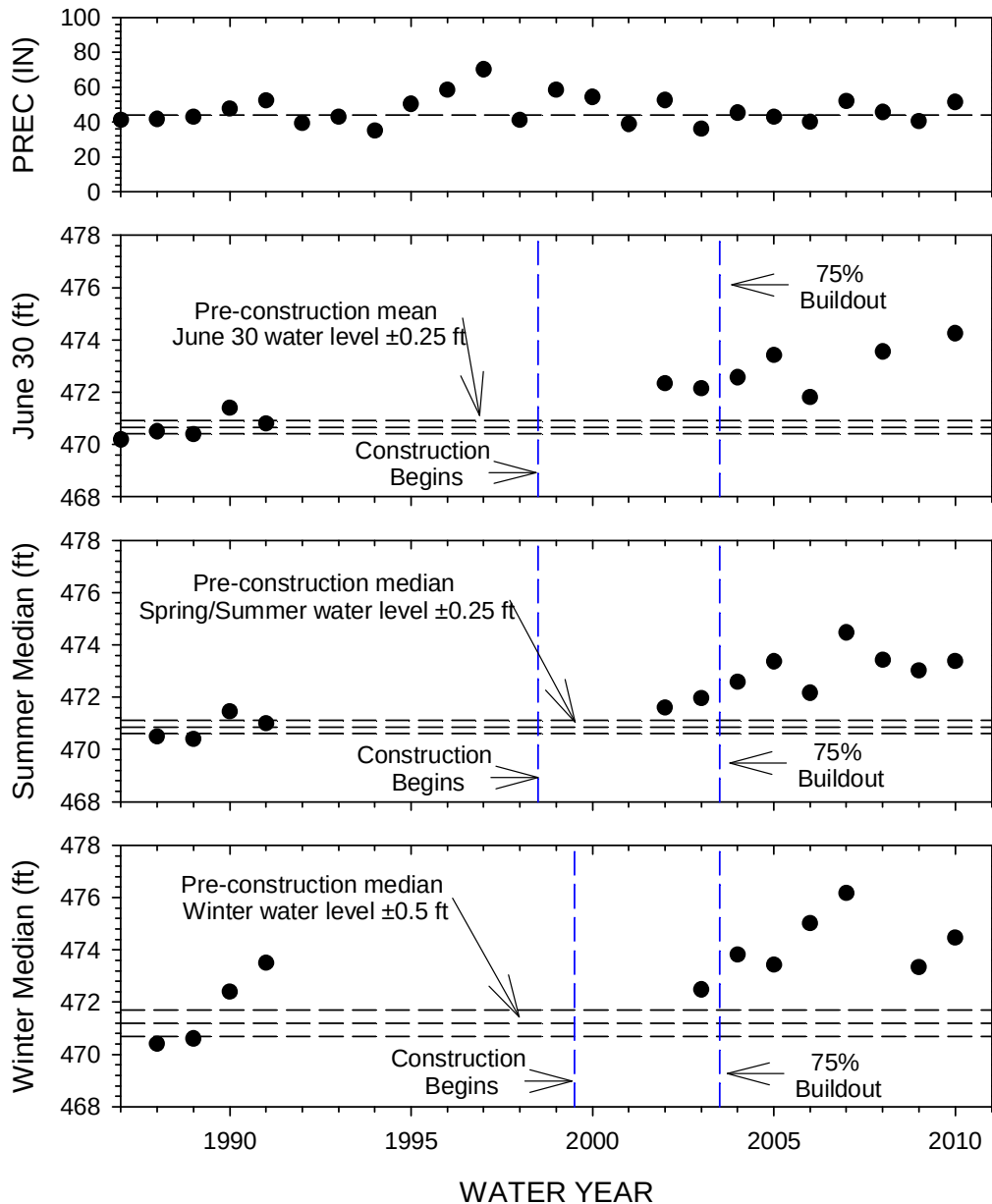


Figure E-7. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland EC-3.

Pre-construction estimates are based on instantaneous staff plate readings conducted approximately monthly, while post-construction estimates are based on daily average levels from continuous gages. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 1999. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Wetland EC-61

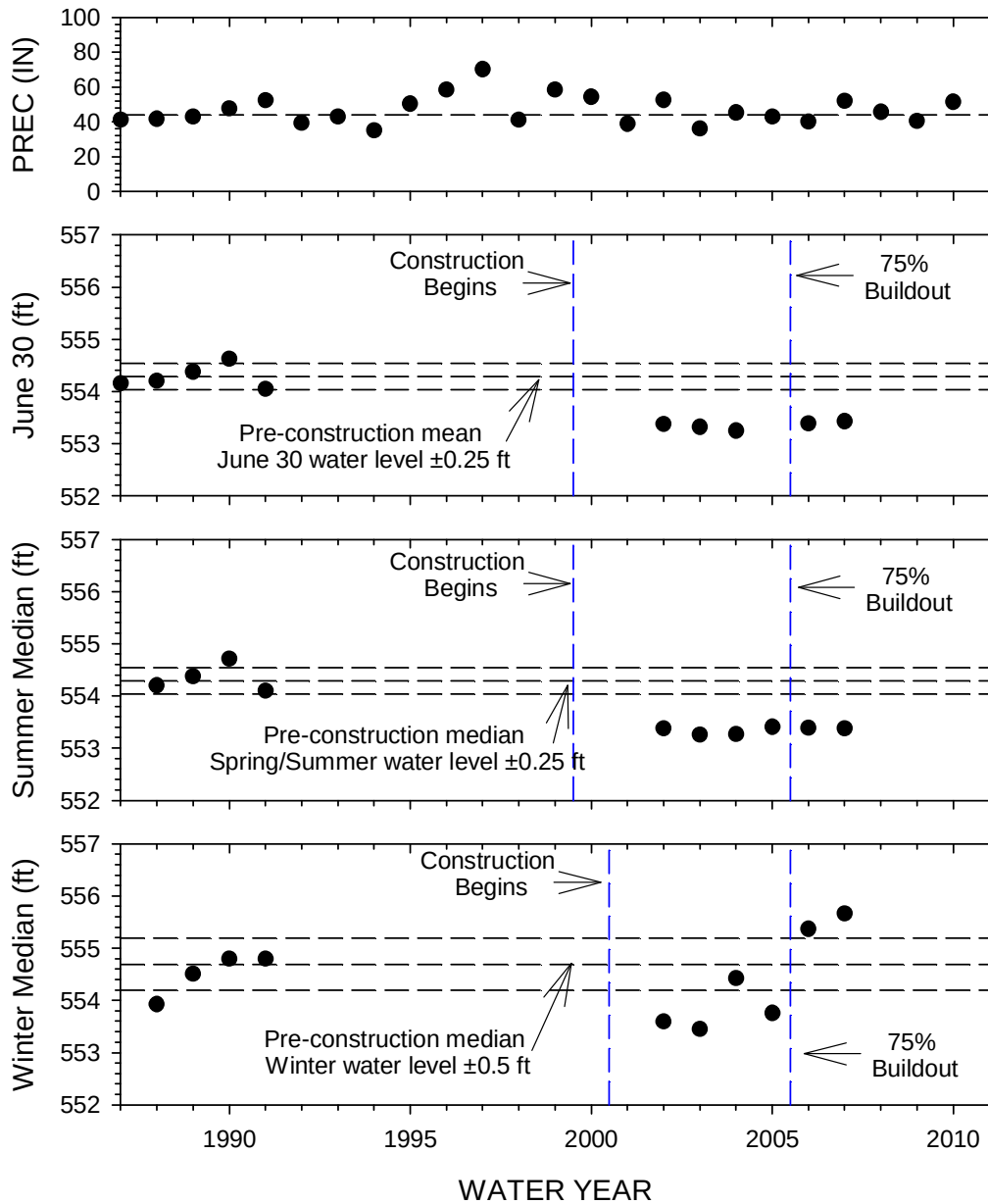


Figure E-8. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland EC-61.

Pre-construction estimates are based on instantaneous staff plate readings conducted approximately monthly, while post-construction estimates are based on daily average levels from continuous gages. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2000. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Wetland EC-4

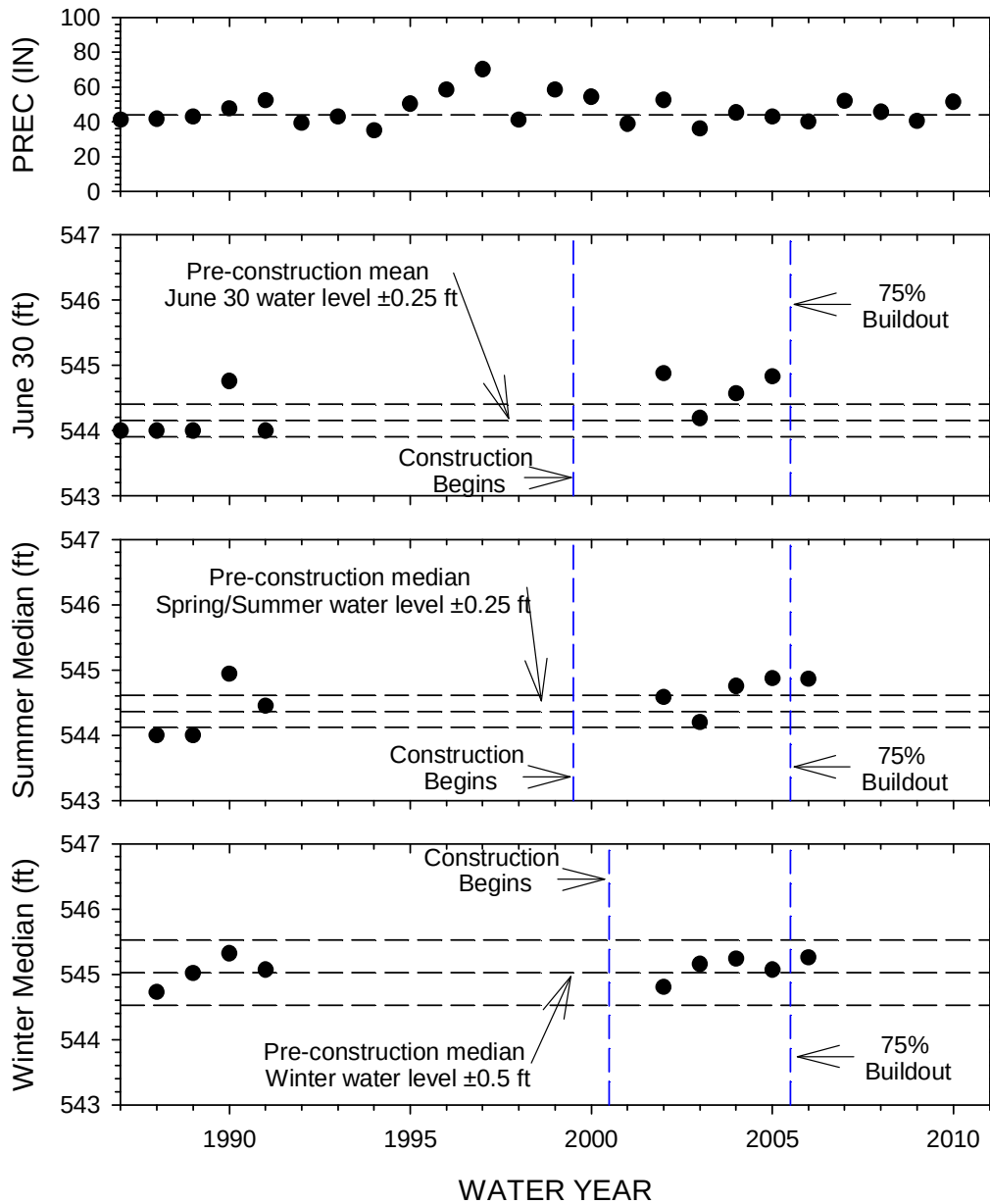


Figure E-9. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland EC-4.

Pre-construction estimates are based on instantaneous staff plate readings conducted approximately monthly, while post-construction estimates are based on daily average levels from continuous gages. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2000. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Wetland BBC-52

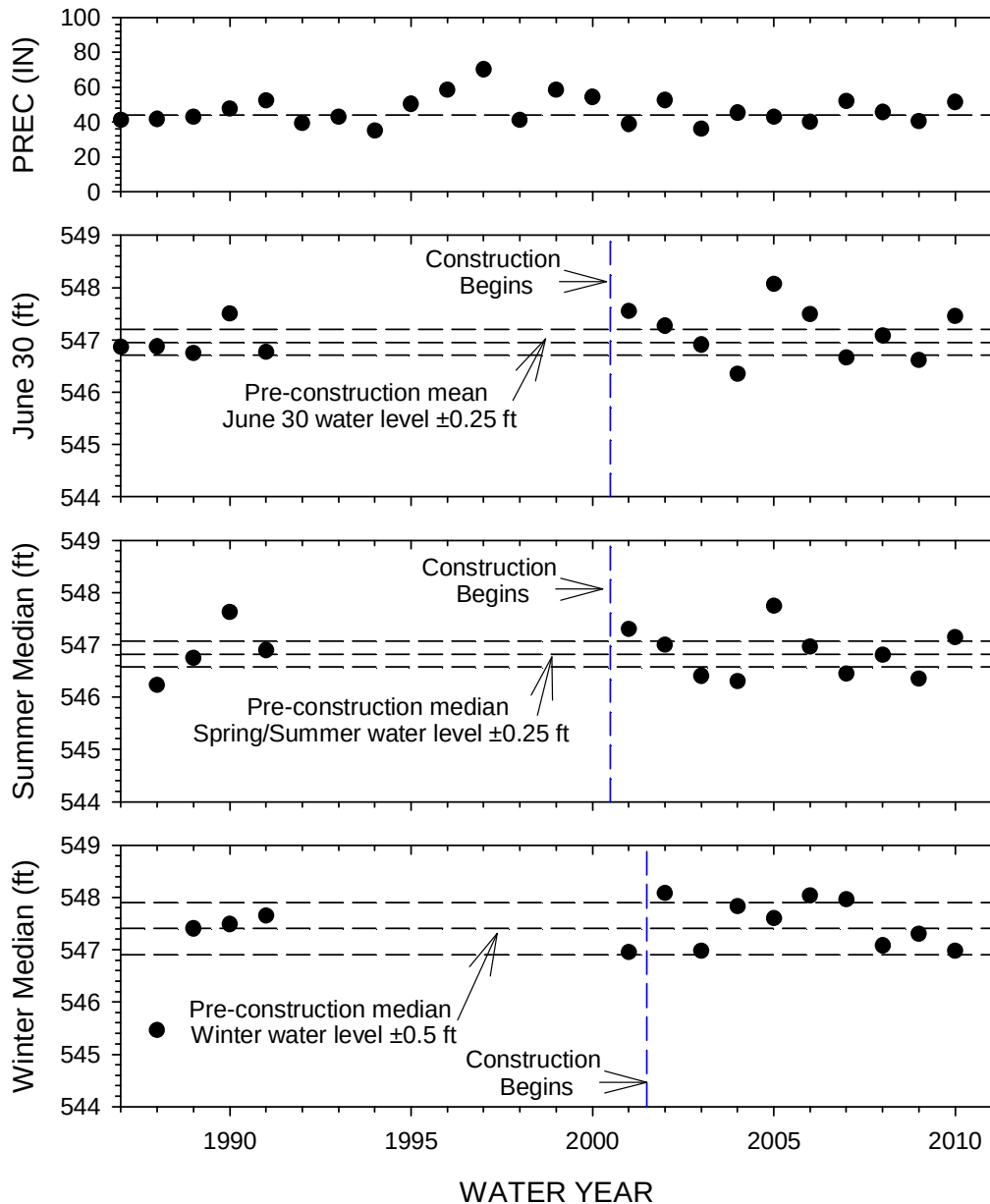


Figure E-10. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland BBC-52.

Pre-construction estimates are based on instantaneous staff plate readings conducted approximately monthly, while post-construction estimates are based on daily average levels from continuous gages. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2001. The vertical dashed line indicates the initiation of construction. This basin has remained relatively undeveloped and has not reached the point of 75 percent buildout.

Wetland BBC-45

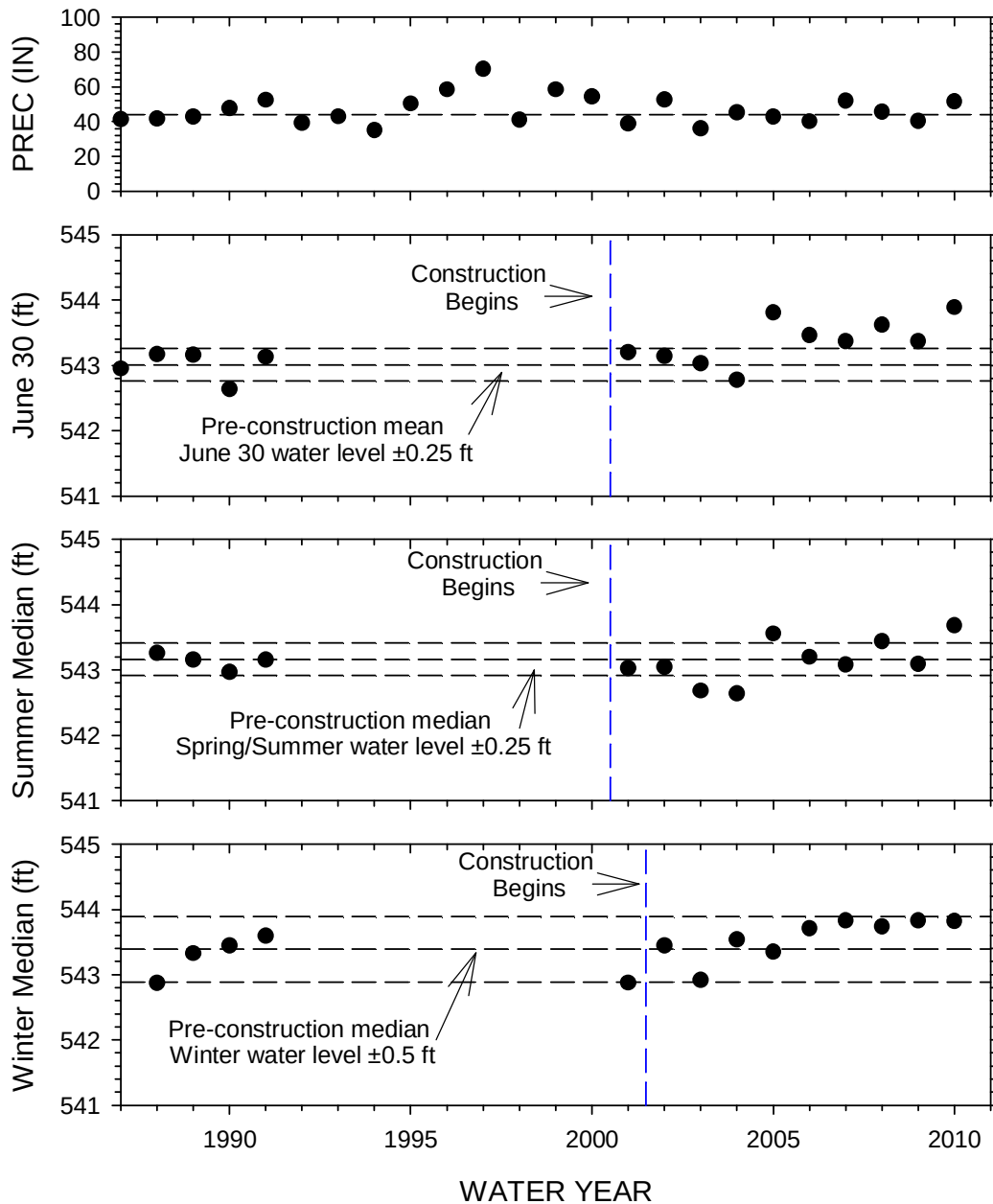


Figure E-11. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland BBC-45.

Pre-construction estimates are based on instantaneous staff plate readings conducted approximately monthly, while post-construction estimates are based on daily average levels from continuous gages. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 2001. The vertical dashed line indicates the initiation of construction. This basin has remained relatively undeveloped and has not reached the point of 75 percent buildout.

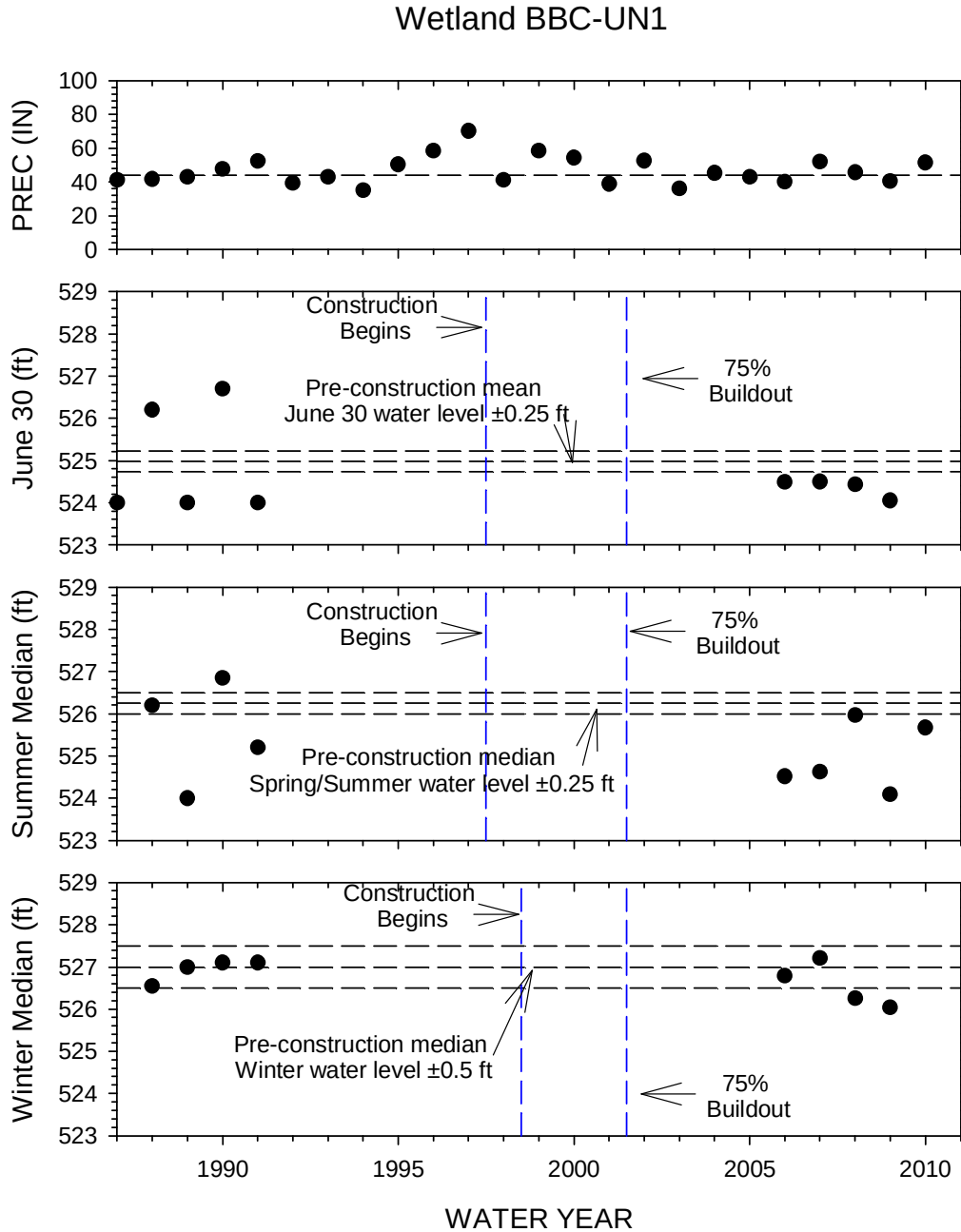


Figure E-12. Estimates of June 30, spring/summer median and winter median wetland water levels in Redmond Ridge wetland BBC-UN1.

Pre-construction estimates are based on instantaneous staff plate readings conducted approximately monthly, while post-construction estimates are based on daily average levels from continuous gages. Top panel shows annual (water year) precipitation totals as filled circles and the dashed horizontal line shows the long term median precipitation. The vertical dashed line indicates the initiation of construction. The shift in the line for winter median levels accounts for the fact that construction began after winter rains in 1998. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by this gage.

Appendix F. Wetland Water Level Fluctuations

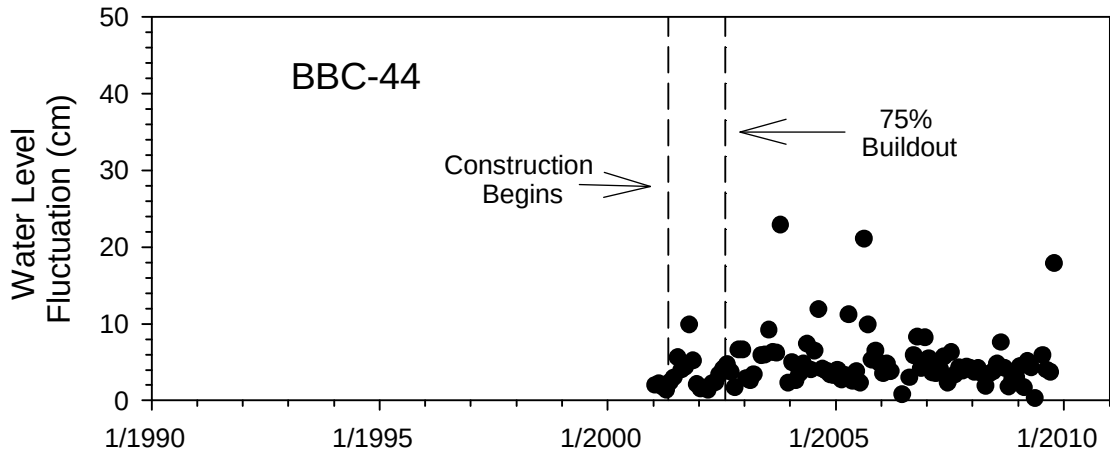


Figure F-1. Estimates of monthly Water Level Fluctuation (WLF) in Trilog wetland BBC-44. No Pre-development data are available for this gage. Monthly post-construction estimates of WLF are based on continuous gage observations. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

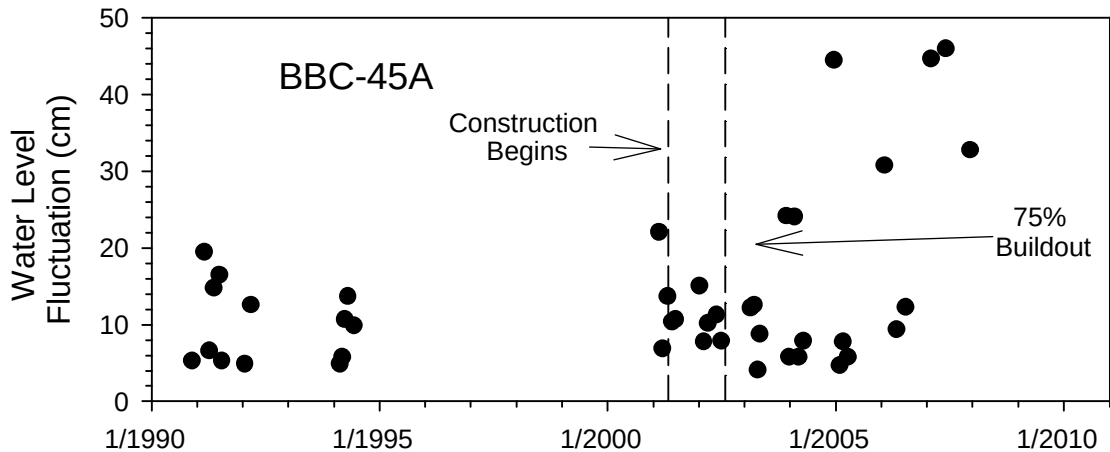


Figure F-2. Estimates of monthly Water Level Fluctuation (WLF) in Trilog wetland BBC-45A. Pre-development and construction data are based on instantaneous and crest stage gage data. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

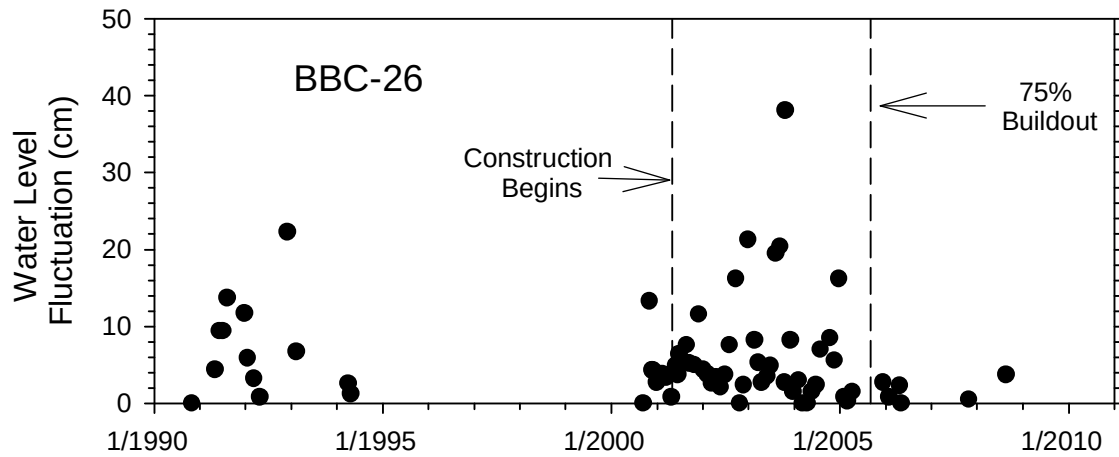


Figure F-3. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetland BBC-26. Pre-development and construction data are based on instantaneous and crest stage gage data. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

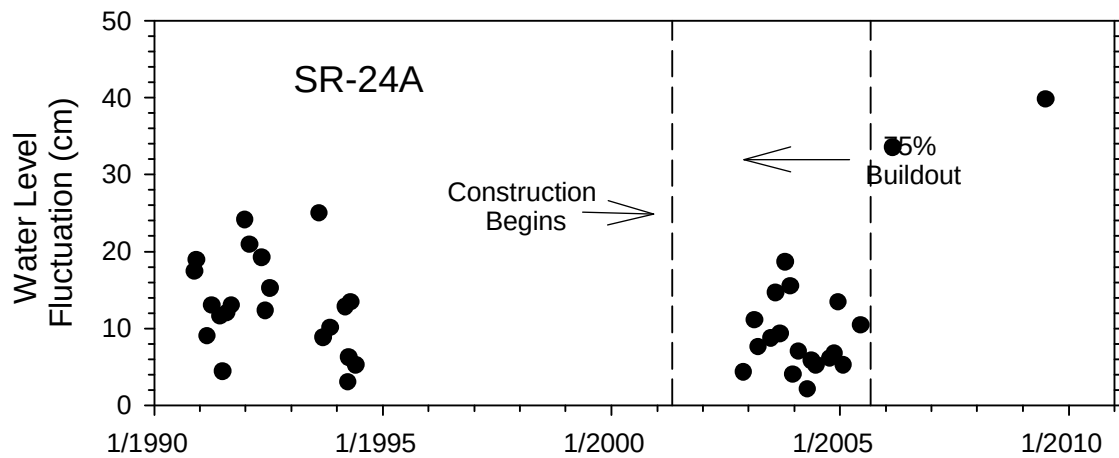


Figure F-4. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetland SR-24A. Pre-development and construction data are based on instantaneous and crest stage gage data. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

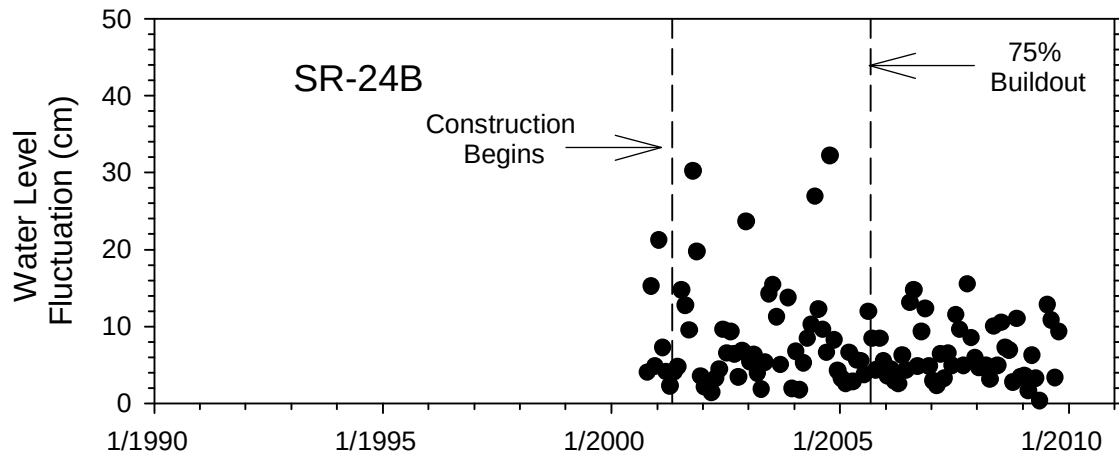


Figure F-5. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetland SR-24B. No Pre-development data are available for this gage. Monthly post-construction estimates of WLF are based on continuous gage observations. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

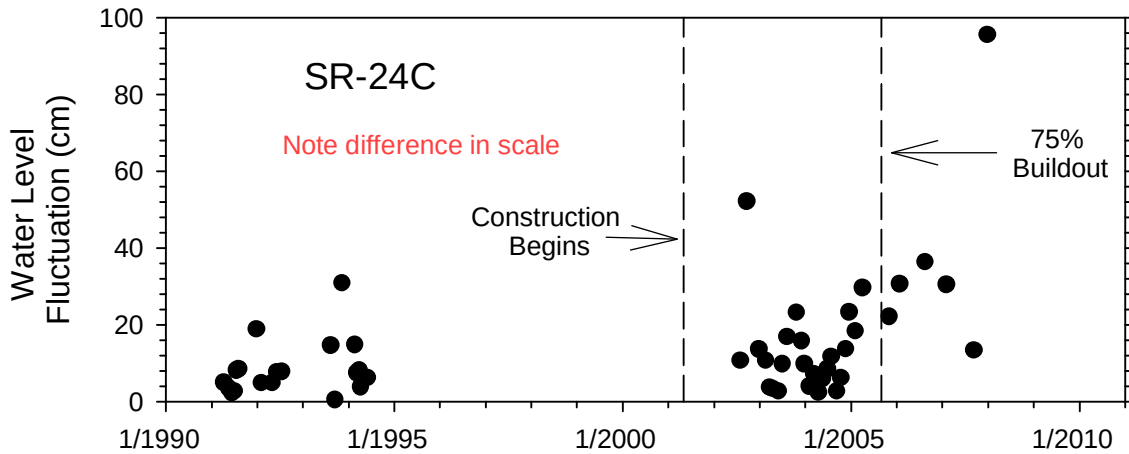


Figure F-6. Estimates of monthly Water Level Fluctuation (WLF) in Trilogy wetland SR-24C. Pre-development and construction data are based on instantaneous and crest stage gage data. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

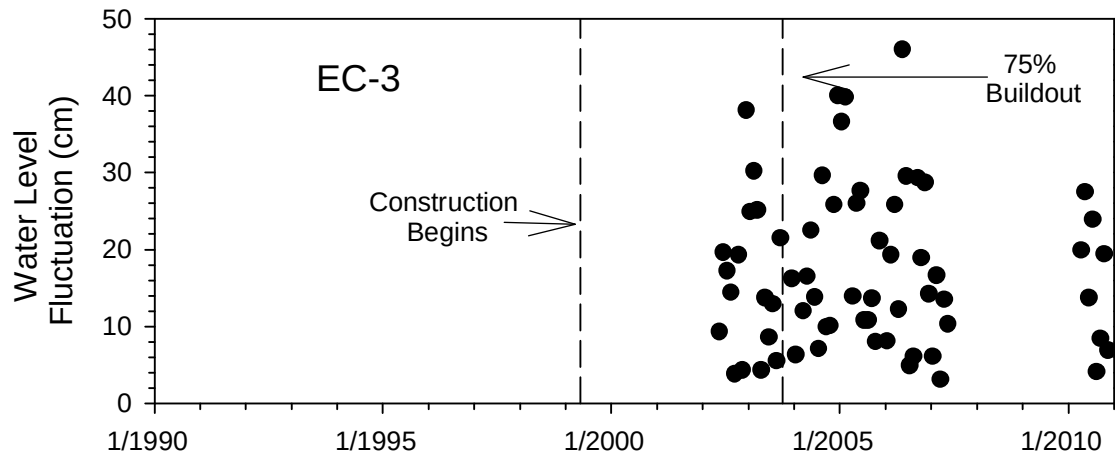


Figure F-7. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland EC-3. No pre-development data are available could be calculated for this gage because no crest stage measurements were made. Monthly post-construction estimates of WLF are based on continuous gage observations. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

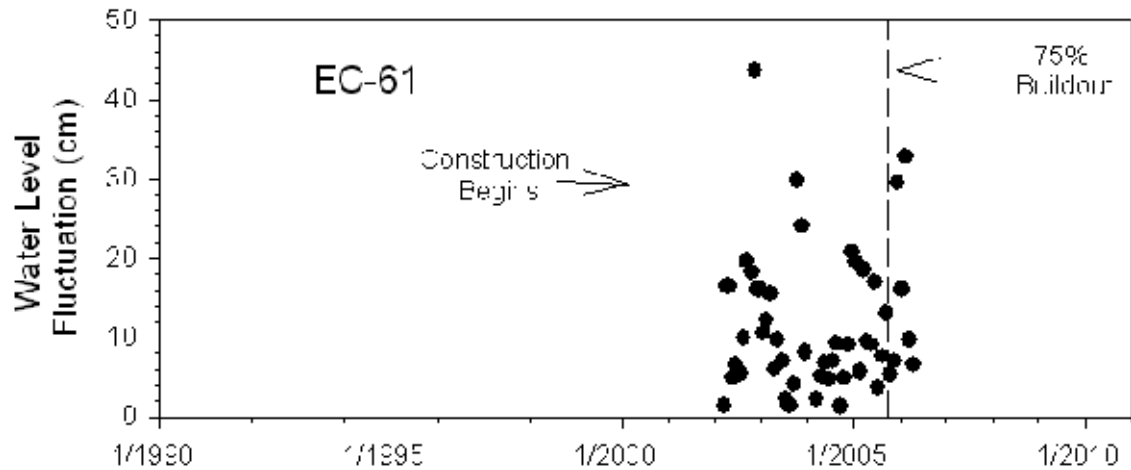


Figure F-8. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland EC-61. No pre-development data are available could be calculated for this gage because no crest stage measurements were made. Monthly post-construction estimates of WLF are based on continuous gage observations. The vertical dashed line indicates the initiation of construction. This basin has remained relatively undeveloped and has not reached the point of 75 percent buildout.

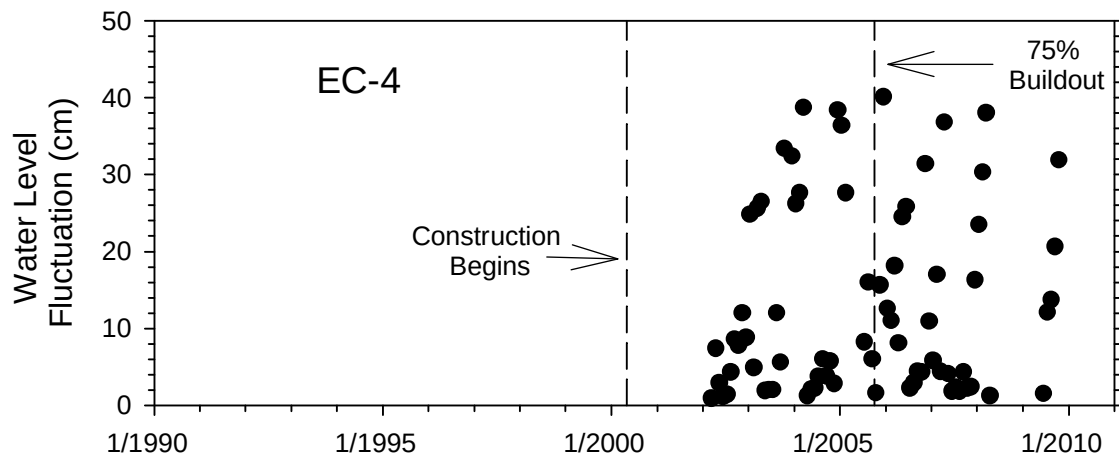


Figure F-9. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland EC-4. No pre-development data are available could be calculated for this gage because no crest stage measurements were made. Monthly post-construction estimates of WLF are based on continuous gage observations. The vertical dashed lines indicate the initiation of construction and point of 75 percent buildout of the basin represented by these gages.

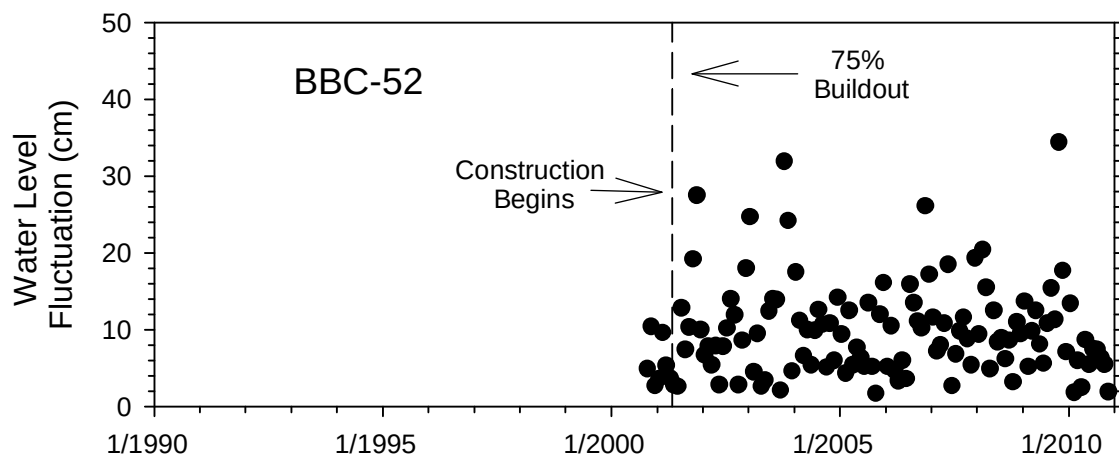


Figure F-10. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-52. No pre-development data are available could be calculated for this gage because no crest stage measurements were made. Monthly post-construction estimates of WLF are based on continuous gage observations. The vertical dashed line indicates the initiation of construction. This basin has remained relatively undeveloped and has not reached the point of 75 percent buildout.

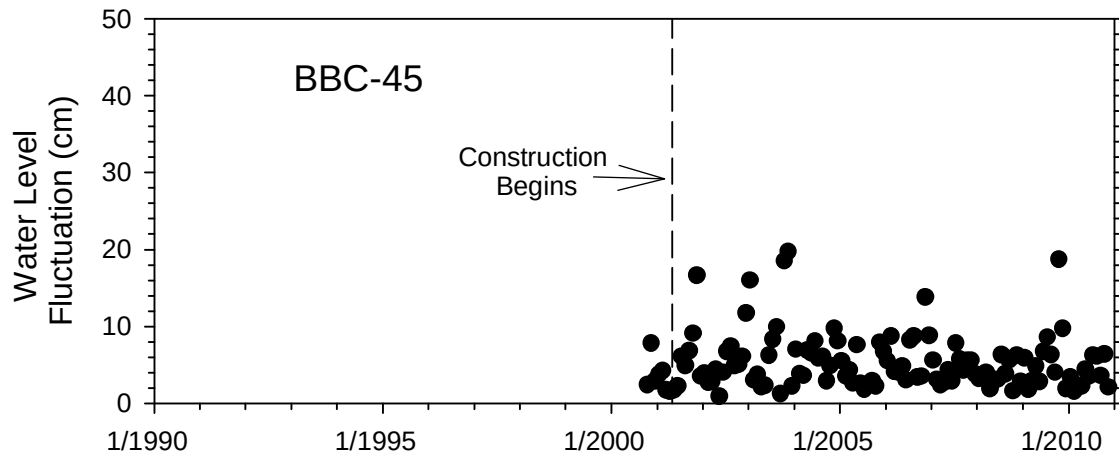


Figure F-11. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-45. No pre-development data are available could be calculated for this gage because no crest stage measurements were made. Monthly post-construction estimates of WLF are based on continuous gage observations. The vertical dashed line indicates the initiation of construction. This basin has remained relatively undeveloped and has not reached the point of 75 percent buildout.

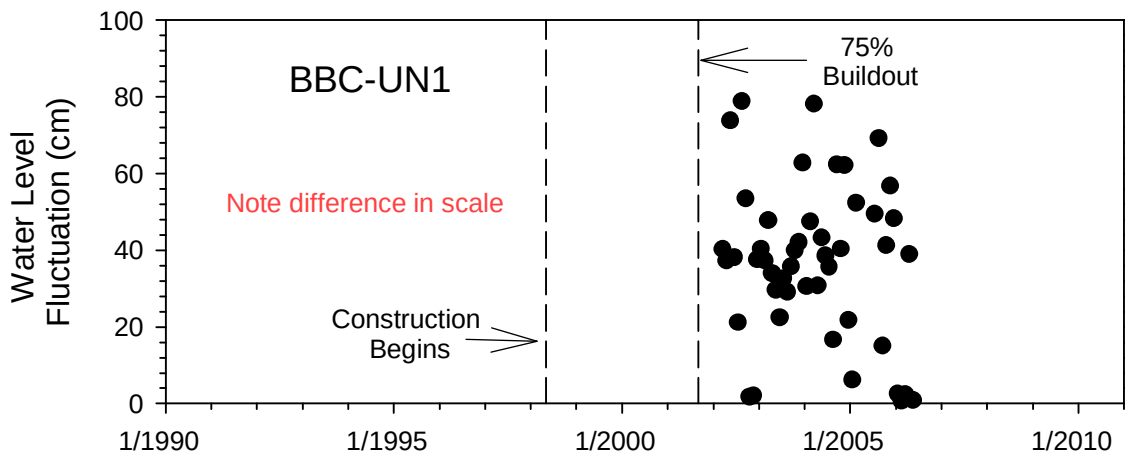


Figure F-12. Estimates of monthly Water Level Fluctuation (WLF) in Redmond Ridge wetland BBC-UN1. No pre-development data are available could be calculated for this gage because no crest stage measurements were made. Monthly post-construction estimates of WLF are based on continuous gage observations. The vertical dashed line indicates the initiation of construction. This basin has remained relatively undeveloped and has not reached the point of 75 percent buildout.

Trilogy and Redmond Ridge Urban Planned Development (UPD) Final Facilities Monitoring Report

Prepared by: David Funke, Engineer, King County Department of Natural Resources and Parks, Water and Land Resources Division. April 2011.



King County

Department of
Natural Resources and Parks

Water and Land Resources Division

201 South Jackson Street, Suite 600
Seattle, WA 98104

TABLE OF CONTENTS

1.0	Introduction	1
2.0	Methods of Data Collection and Analysis	6
2.1	Precipitation Monitoring.....	6
2.2	Stormwater Flow Control Facilities Continuous Monitoring	9
2.3	Crest-Stage Monitored Facilities.....	11
2.4	By-pass Pipeline Monitoring	11
3.0	Results and Discussion	12
3.1	Precipitation Monitoring.....	12
3.2	Stormwater Flow Control Facilities Continuous Monitoring	13
3.3	Bypass Pipeline Monitoring.....	19
4.0	References	22

TABLES

Table 1.	List of Monitored Flow Control Facilities	4
Table 2.	Water level recording instruments at the UPD facilities.	9
Table 3.	Target flow rates for UPD Detention Facilities.	11
Table 4.	Significant precipitation events during facilities monitoring period.....	13
Table 5.	Summary of overflow observations for crest-stage gages at five Redmond Ridge stormwater facilities.	18

FIGURES

Figure 1.	Location map of flow control facility and other hydrologic monitoring locations in the Trilogy and Redmond Ridge Urban Planned Developments.....	5
Figure 2.	Rain gage locations in the Redmond Ridge and Trilogy UPDs.....	7
Figure 3.	Rain gage 02V and Trilogy_met monthly rainfall totals for 2008 through 2011	8
Figure 4.	Maximum 24-hour discharge from stormwater pond ECW1B1 and 24-hour rainfall totals.....	14
Figure 5.	Maximum 24-hour discharge from stormwater pond ECW3-1 and 24-hour rainfall totals.....	16
Figure 6.	Maximum 24-hour discharge from stormwater pond EC2-1 and 24-hour rainfall totals.....	17

Figure 7. Maximum 24-hour discharge from stormwater pond NWD1-A and 24-hour rainfall totals.....	18
Figure 8. Maximum daily flow for Wallace Creek West (53B) and Wallace Creek bypass (53F), plus maximum daily rainfall.....	19
Figure 9. Maximum daily flow for Adair Creek (53A) and Adair Creek bypass (53D), plus maximum daily rainfall.....	21

1.0 INTRODUCTION

Trilogy (formerly Blakely Ridge) and Redmond Ridge (formerly Northridge) are adjoining Urban Planned Developments (UPDs) located on approximately 2,560 acres (1,035 hectares) in north central unincorporated King County, Washington. This report presents the results from monitoring of flow control facilities conducted with the intent of ensuring that the UPDs did not significantly disrupt the predevelopment hydrology. The hydrologic monitoring methods followed recommendations specified in the original Redmond Ridge and Trilogy post-development monitoring plans (King County, 1999 and 2001) and are described in more detail in King County (2010). The flow control facility hydrologic monitoring locations evaluated in this report are shown in Figure 1.

The overall goal of the hydrologic monitoring was to determine if there were unexpected changes in the hydrology of streams and wetlands as a result of UPD construction and development. A complex system of stormwater controls was built into both UPDs to maintain the hydrologic response of the streams and wetlands near their predevelopment condition. The facilities use infiltration ponds, detention ponds, and bypass pipelines to control the volume and rate of stormwater runoff to the wetland and stream receiving water bodies. The post-development monitoring of facilities was intended to assess the facility performance in meeting the flow control objectives.

Performance criteria were established in the Drainage Master Plans (DMP) for Trilogy (Northwest Engineering, 1995) and Redmond Ridge (Hugh Goldsmith & Associates, 1996) that were used to site and size stormwater control facilities to:

- Minimize the potential impacts on wetland water levels to protect wetland flora and fauna,
- Maintain peak flood flows at predevelopment levels so as not to impact downstream conveyance or increase downstream flooding, and
- Maintain developed condition flow durations below the predevelopment flow durations between one-half of the predevelopment 2-year peak flow to the 100-year return flow to prevent destabilization of the geomorphic balance of the stream system downstream of the development.

The specific guidance for the design of stormwater detention facilities was given such that the discharge from developed areas shall be no more than:

- Fifty percent of the forested 2-year 24-hour release rate for design storm events up to and including the 2-year / 24-hour design storm event;
- The forested 2-year / 24-hour release rate for design storm events greater than the 2-year / 24-hour design storm event and up to and including the 10-year / 24-hour design storm event; and

- The forested 10-year / 24-hour release rate for design storm events greater than the 10-year / 24-hour design storm event and up to and including the 100-year / 24-hour design storm event.

The engineering design for the UPD stormwater controls relied on hydrologic simulation models to evaluate the effects of the development on stream and wetland hydrology and to evaluate the ability of the stormwater flow control facilities to mitigate the impacts of development on hydrology. A predevelopment condition was modeled using continuous simulation models (Hydrological Simulation Program–Fortran or HSPF)¹ that were calibrated to stream flow and wetland level measurements made before development was initiated. The calibrated models were then used to represent fully developed conditions, including stormwater control facilities that were then sized through an iterative modeling process comparing developed to pre-developed condition model output until the performance criteria outlined above were met.

The Redmond Ridge and Trilogy post-development monitoring plans (King County, 1999 and 2001) give the following criteria for the evaluation of stormwater flow control facilities:

1. Detention (flow control) facilities do not store and release stormwater within a 20% margin of the expected levels and flows. (Volume released for an observed storm is 20% different than the model predicted).
2. Bypass flows occurring during flow plus or minus 20% of the DMP settings.

The comparison to modeled design flows assumes that the modeled flows are accurate representations of flows that would occur from the constructed facilities. However, a preliminary evaluation of the available HSPF models indicated that they were calibrated to a limited period of data and were not calibrated to match specific discharge return frequencies. Although the models were suitable for designing the UPD stormwater facilities, they may not be suitable for direct comparison to observed data unless the models were re-calibrated and the errors quantified to determine the magnitude of the difference between observed and modeled return flows that could be detected reliably. However, such a “synthetic paired basin approach” (Hartley and Funke 2001) is beyond the scope of this evaluation.

Detention facilities were evaluated by comparing recorded daily peak discharge to the design benchmarks. Three significant benchmarks used in the design of the flow control facilities were the 2-year, 10-year, and 100-year annual peak events. These terms represent the streamflow or wetland level that had a 50 percent, 10 percent, or 1 percent probability, respectively, of being the highest in any particular year of the model output set. Detention facilities were designed so that the 2-year peak discharge was one-half of the predevelopment 2-year flow from the same contributing area. The 10-year pond discharge was to match the 2-year predevelopment flow, and the 100-year pond discharge was to match the 10-year predevelopment flow. Flow splitters to the bypass pipelines for Adair Creek and Wallace Creek were designed to keep post-development peak flows and flow durations equal to or less than predevelopment peak flows and durations for all discharges above one-half of the predevelopment 2-year return flows. Any

¹ HSPF is a continuous simulation hydrologic model supported by the U.S. Geological Survey and the Environmental Protection Agency (Bicknell et al., 2005)

flows that exceeded the 2-year target were investigated using the evaluation procedure described in Appendix C in the Post-Development Monitoring Plan for the Trilogy at Redmond Ridge UPD (King County, 2001).

Three stormwater facilities in Redmond Ridge and one in Trilogy were monitored using continuous water level recorders installed in the outlet control structure catch basin of each facility. All four facilities discharge to wetland buffer areas. Five Redmond Ridge facilities were monitored with crest-stage gages to detect any pond levels above the 100-year design level. These ponds either infiltrate to groundwater or outlet to a wetland buffer. Two bypass pipelines were monitored with continuous recorders to assess the function of the bypass system. The bypass pipes discharge to a conveyance channel connected to the Snoqualmie River. Elements of the public stormwater system in the UPDs become the responsibility of King County upon County acceptance. Table 1 lists the facilities monitored for hydrologic performance with the facility label referenced in design documents, development name, monitoring method, King County Facility ID, and date of County acceptance or status. Acceptance of a facility for County ownership is determined independently of the assessment of hydrologic performance discussed in this document.

Table 1. List of Monitored Flow Control Facilities

Facility Label	Development	Monitoring Method	KC Facility ID	Date KC Accepted
ECW1B1	Redmond Ridge	Continuous	D92822	6/4/2008
ECW3-1	Redmond Ridge	Continuous	D92836	6/4/2008
ECW2-1	Redmond Ridge	Continuous	D92835	6/4/2008
NWD1-A	Trilogy	Continuous	D92934	3/27/2009
BC2-1	Redmond Ridge	CSG	D92965	On maintenance bond
ECW3-3	Redmond Ridge	CSG	D92849	6/4/2008
MC1-1	Redmond Ridge	CSG	D92758	6/4/2008
MC2-1	Redmond Ridge	CSG	D92759	6/4/2008
MC4-1	Redmond Ridge	CSG	D92760	6/4/2008
Adair Cr Bypass	Trilogy	Continuous	n/a	n/a
Wallace Cr Bypass	Trilogy	Continuous	n/a	n/a

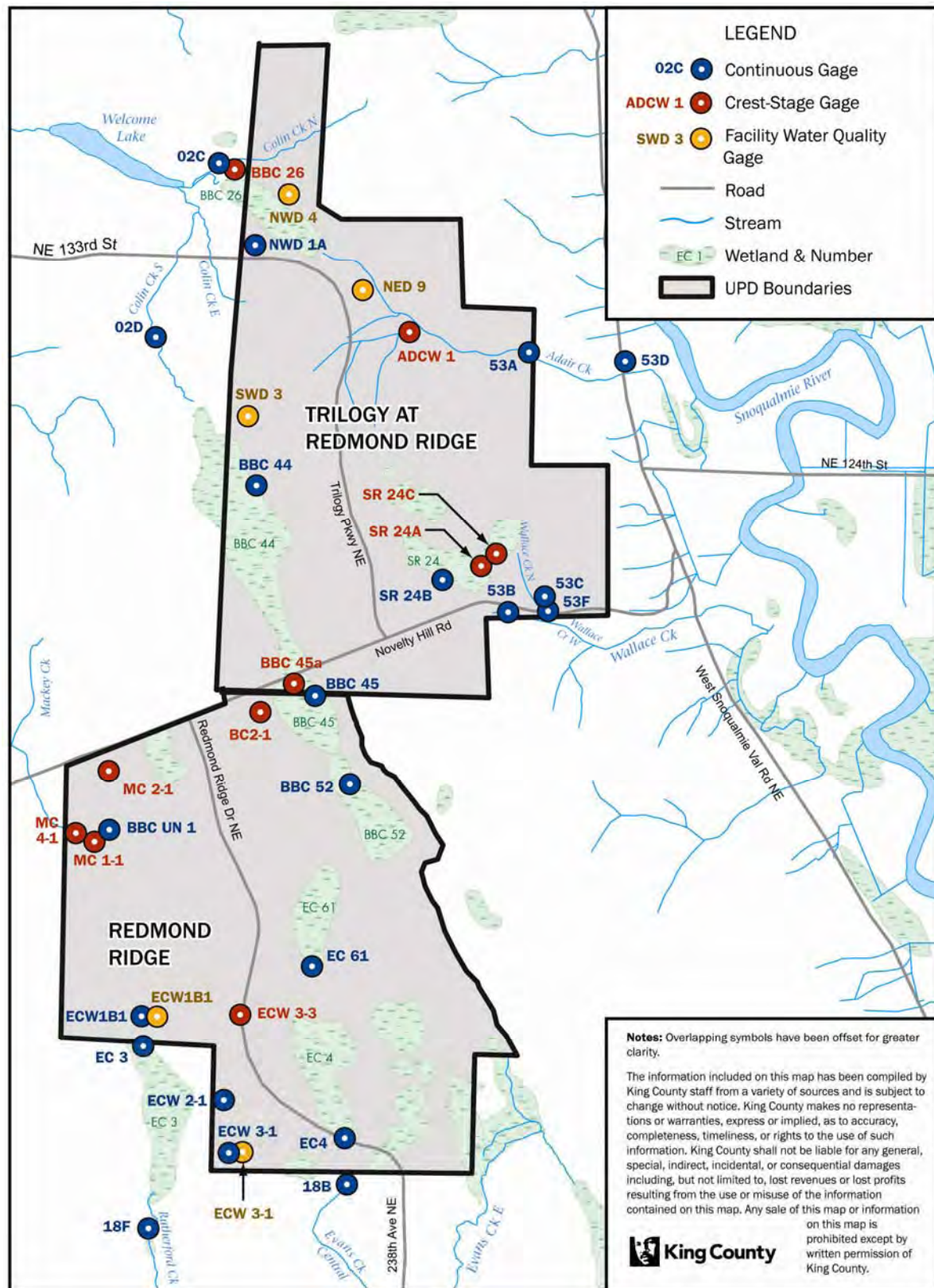


Figure 1. Location map of flow control facility and other hydrologic monitoring locations in the Trilogy and Redmond Ridge Urban Planned Developments.

2.0 METHODS OF DATA COLLECTION AND ANALYSIS

2.1 *Precipitation Monitoring*

Because the surface water hydrologic processes in the UPDs are closely linked to the timing, intensity and duration of rainfall, precipitation data provide context for considering how hydrologic data should be interpreted. Precipitation has been monitored continuously by the King County Water and Land Resources Division (KCWL RD) since May 1995² at Station 02V located 2,000 ft west of the Trilogy UPD on NE 133rd Street. Since May 31, 2005, KCWL RD has downloaded hourly rainfall data from the Trilogy Golf Course rain gage (Trilogy_met) located at 11425 - 234th Place NE, near Novelty Hill Road. In March 2010, KCWL RD established rain gage 18V2 in the ECW2-1 detention facility to support monitoring for another project. The locations of the three active rain gages in the UPD area are shown in Figure 2.

A variety of problems at the 02V rain gage led to missing data in nine different months during the 2008–2010 period. For this reason, data from the Trilogy_met gage were used to generate rainfall intensity data used in this report. The Trilogy_met gage is within two miles of every area in each of the UPDs (Figure 2). The Trilogy_met gage tends to record about five percent less rainfall than 02V. Figure 3 gives a comparison of monthly totals from 02V and Trilogy_met for the monitoring period. Periods of missing data at 02V have been estimated.

Procedures

Hourly rainfall data for October 2008 –December 2011 was loaded in a spreadsheet. A running 24-hour total was calculated and the maximum 24-hour total for each day extracted to a new data set. The maximum 24-hour rainfall total for each day was plotted with the flow data. This gives a graphical representation of peak rainfall intensities. Calendar day rainfall totals were used to calculate multiday rainfall for analyzing specific flow events.

² 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.

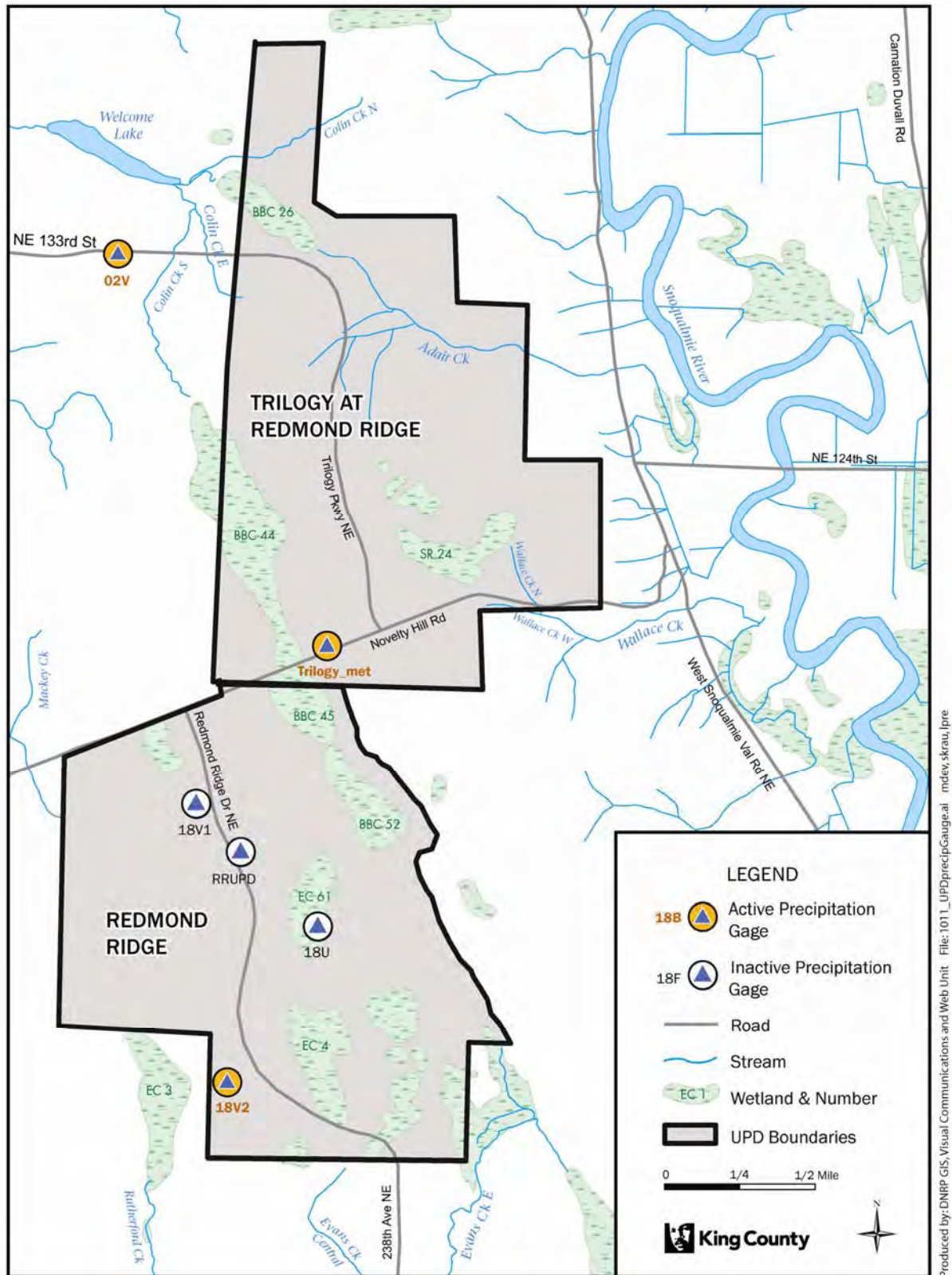


Figure 2. Rain gage locations in the Redmond Ridge and Trilogy UPDs.

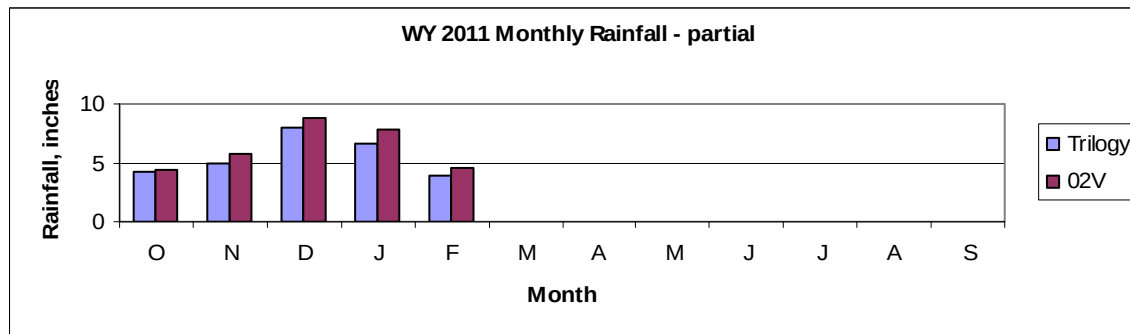
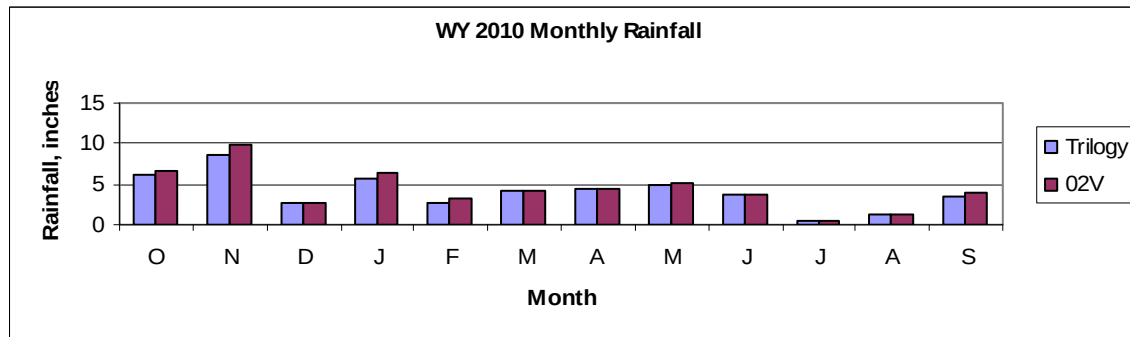
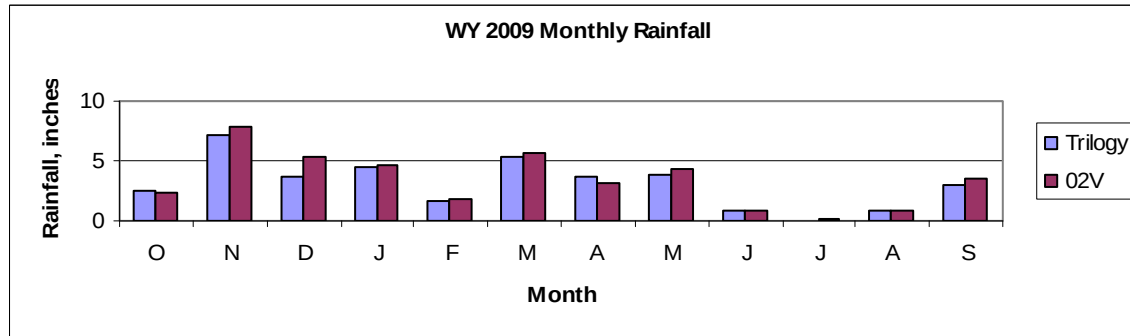
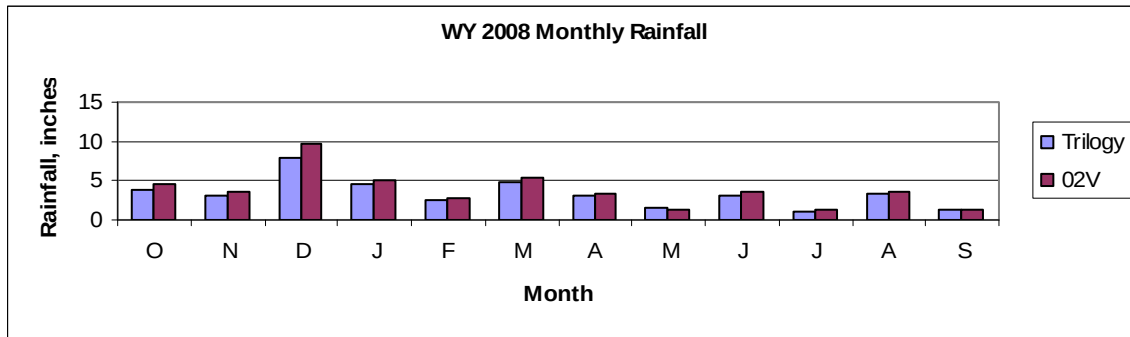


Figure 3. Rain gage 02V and Trilogy_met monthly rainfall totals for 2008 through 2011

2.2 Stormwater Flow Control Facilities Continuous Monitoring

In 2011, KCWLRD completed the assessment of three stormwater detention facilities in Redmond Ridge and one in Trilogy using continuous water level recorders installed in the outlet control structure basin of each facility. During site visits, visual inspection was made of the facility outfalls to look for erosion and concentrated flows damaging the wetland buffer. Peak daily discharge for each facility was plotted with 24-hour rainfall intensity and design target stormflows for two-, ten- and 100-year return intervals. Facility performance was evaluated by comparing pond discharge to the design target flows and measured rainfall intensity.

Procedures

Continuous water level monitoring of each facility was accomplished with a programmable water level recorder installed in the control structure. The monitoring plans call for instrument accuracy of 1 percent of the full range of levels to be measured. A fluctuation of up to ten feet from zero flow to overflow could be expected at any of the monitored facilities. Table 2 gives the locations, instruments used and instrument accuracy. Water level was recorded every 15 minutes.

Table 2. Water level recording instruments at the UPD facilities.

Location	Flow Meter	Date Range	Range (feet)	Minimum Accuracy (+/- feet)	Manufacturer
ECW1B1	Isco 4230	2/26/2008 - 8/26/2009	10	0.04	Teledyne Isco, Inc iscoinfo@teledyne.com
ECW1B1	Onset U20-04	8/26/2009 - 10/22/2010	13	0.04	Onset Computer Corporation, www.onsetcomp.com
ECW1B1	Solinst LT 3001	11/14/2003 - 2/26/2008	16	0.03	Solinst Canada Ltd., www.solinst.com/
ECW3-1	Isco 4230	2/26/2008 - 8/26/2009	10	0.04	Teledyne Isco, Inc iscoinfo@teledyne.com
ECW3-1	Onset U20-04	8/26/2009 - 10/22/2010	13	0.04	Onset Computer Corporation, www.onsetcomp.com
ECW2-1	Onset U20-04	10/29/2009 - 2/4/2011	13	0.04	Onset Computer Corporation, www.onsetcomp.com
NWD1-A	Onset U20-04	10/29/2009 - 10/22/2010	13	0.04	Onset Computer Corporation, www.onsetcomp.com
53D	Onset U20-04	10/3/2008 - 10/22/2010	13	0.04	Onset Computer Corporation, www.onsetcomp.com
53D	Ott Thalimedes	11/17/2004 - 11/6/2006	5	0.01	Hach Hydromet Inc, www.hydrolab.com/web/ott_hach
53F	Isco 4230	3/23/2005 - 10/9/2008	10	0.04	Teledyne Isco, Inc iscoinfo@teledyne.com
53F	Isco 4150	10/9/2008 - 2/4/2011	5	0.03	Teledyne Isco, Inc iscoinfo@teledyne.com

The relative elevations of the flow restrictors, outlet, and top of structure were verified to the design specifications by inspection. Water level in the control structure was determined by measuring from the top of the structure with steel engineer scale tape or an electronic water level indicator graduated in 1/100ths of a foot. Recorded water level was converted to outlet head and pond discharge computed from the design stage-discharge rating. Where feasible, outlet discharge was verified periodically with a direct measurement using a Swoffer 2100 flow meter to record depth and velocity readings at a minimum of three locations across the channel. Documentation of the data set preparation is stored in hard copy files. Data are available for download by searching for the WLR Gage Number at the website: <http://green.kingcounty.gov/wlr/waterres/hydrology>.

For each facility, the design assumptions and calculations, model rating curves, and design drawings were extracted from the Stormwater Facility Technical Information Report copy stored in the KCWLRD Stormwater Library at King Street Center. Design flow through the flow control structure restrictor plates was independently calculated. The verified design flows were used to create an expanded rating table matching water level above the invert of the outlet pipe to a corresponding flow in cubic feet per second (cfs). At least two manual measurements of discharge from the pond outlet were made for each site. This was done by measuring the water level at pipe end, and measuring the velocity with a Swoffer 2100 flow meter. The outlet to ECW3-1 was always submerged to the extent no measurement of velocity could be made. The outlets of the other facilities were similarly inundated during high flow periods and no measurements were made then.

The facilities monitoring was to be completed by October 2010. The level recorders were removed for all sites except ECW2-1 where another project³ was monitoring pond inflow. A 3.2 inch in 24-hour rain storm occurred December 12–13, 2010. Each facility was visited after that storm to estimate the peak level from high water marks and to investigate the condition of the wetland buffer at the outlet. The high water marks enabled a determination of peak flow for the facility during the December storm. This observation is included in the results discussion.

Analysis of flows from the facilities is not strictly quantitative. The chart for each site plots the peak discharge for each day with the peak 24-hour rainfall intensity for the day. Lines for target flows and design rain storms are shown for reference (Table 3). The chart makes readily apparent periods when peak pond discharge exceeds the target flows. Flows below the 2-year target are assumed to be insignificant. Flows above the 2-year target are investigated. Peak flows that exceed a target flow but that occur with a rain storm intensity that matches the corresponding design rain storm total are considered evidence of proper pond function. Other situations when target flows are exceeded but may not be evidence of pond malfunction include (1) precipitation events with many consecutive days of rain, or (2) snow accumulations that melt rapidly with a heavy rain. Flows exceeding the 2-year target in response to typical rain intensities should not occur and may be evidence of improper pond functioning. The 20 percent allowable deviation from design flows is taken into account in assessing whether threshold criteria have been exceeded. To be significant (i.e. warranting corrective action), flows that

³ King County BMP Effectiveness Monitoring Conducted Under the Phase 1 Municipal Stormwater Permit WAR04-4501. Study compares runoff from an area of amended soils to runoff from an area with no soil amendment. Pond ECW2-1 had two main inlets, only one is monitored for this project.

exceed the threshold criteria should have a noticeable negative effect on the hydrologic function of the receiving water.

Table 3. Target flow rates for UPD Detention Facilities.

	Design Rain Storm	2-yr rain 1.9 inches	10-year rain 2.9 inches	100-yr rain 3.9 inches
Facility Label	Contributing Area acres	2-year Target, cfs	10-year Target, cfs	100-year Target, cfs
ECW1B1	45.3	0.54	1.07	2.87
ECW3-1	35.28	0.62	1.33	3.05
ECW2-1	18.04	0.22	0.44	1.23
NWD1-A	22.87	0.46	0.66	1.82

2.3 Crest-Stage Monitored Facilities

Five stormwater flow control facilities in the Redmond Ridge UPD were monitored for any evidence of high stages or overflows for storms below the 100-year rainfall accumulation (3.9 inches). In 2003, crest-stage recorders were installed in five ponds (BC2-1, MC2-1, MC4-1, MC1-1, and ECW3-3). The recorders consist of a post with an attached five-foot long, two-inch diameter PVC stand pipe, capped on the bottom and with an indicator rod inside. Holes are drilled near the bottom of the pipe to allow water in so the water level in the pipe corresponds to the pond level. Granulated cork placed in the pipe floats with the water and then adheres to the indicator rod at the highest level the water reaches. The top of the pipe was surveyed in relation to the elevation of the pond overflow structure. The gages were observed at monthly intervals initially, and then only after large storms or twice annually. The results of the observations were kept in paper files and an electronic spreadsheet.

2.4 By-pass Pipeline Monitoring

High flow bypass pipelines are employed to divert some stormwater runoff out of the natural channels for Adair Creek and Wallace Creek. Charts of the daily peak gaged flow in the bypass pipeline and the associated stream visually demonstrate the success of the bypass systems in reducing peak flows in the natural channel. The bypass system should convey stormwater and result in a flow regime in the creek that is consistent with that in a relatively undeveloped basin.

Gage 53F Wallace Creek Bypass Pipeline

Monitoring of the Wallace Creek bypass began March 22, 2005 and was completed February 4, 2011. Flow is conveyed through a pipe system to an energy dissipater below West Snoqualmie Valley Road (Figure 1). Flow in the pipe system is shallow with high velocity, and these characteristics make discharge difficult to measure. A manhole in the system above the SED 1 facility was chosen to measure flow. Overflow from SED 1 is conveyed to the bypass, so any of that flow was not measured. The manhole used is close to the surface, and the pipe slope is relatively flat compared to the rest of the pipe below SED 1. 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. The Isco 4230 was replaced in fall 2008 with an Isco 4150 flow meter using a low profile velocity-area sensor. This instrument required less maintenance and gave a more complete record than the 4230.

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.

Gage 53D Adair Creek Bypass Pipeline

Monitoring of the Adair Creek high flow bypass began May 1, 2003 and was completed October 22, 2010. 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. A set of direct measurements of discharge made below the weir were used to create a stage–discharge rating. Rate of flow was determined by measuring water level behind the weir and converting the level to discharge with the rating table. The configuration of the outlet from the energy dissipater does not provide accurate determination of discharge, because 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. Flows in 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 2008 water year are available. A new sensor and recorder was made available and installed for the 2009 and 2010 water years.

3.0 RESULTS AND DISCUSSION

3.1 Precipitation Monitoring

During the October 2007 through December 2011 facilities flow monitoring period, a number of significant precipitation events occurred (Table 4.) These events either were associated with flows in a facility that approached or exceeded a threshold criterion, or were of a design event magnitude.

Table 4. Significant precipitation events during facilities monitoring period.

Event	Date	Rainfall amount	Comment
1	December 3, 2007	3.7 inches / 24 hours	95% of 100-year design storm
2	November 7 - 14, 2008	5.8 inches / 10 days	7 day total of 4.2 inches was close to 2-year 7 day design storm, followed by 1.5 inches in 36 hours.
3	January 7 - 13, 2009	6 inches / 17 days	Rain fell on 6 - 10 inches of accumulated snow
4	November 5 - 27, 2009	8.5 inches / 22 days	20% greater than average November total
5	October 10, 2010	1.8 inches / 24 hours	95% of 2-year design storm total
6	December 13, 2010	3.2 inches / 24 hours	25-year design storm

3.2 Stormwater Flow Control Facilities Continuous Monitoring

ECW1B1

Continuous water level monitoring commenced at stormwater facility ECW1B1 on November 14, 2003. Data through September 2007 were analyzed in the 2007 UPD annual report (King County, 2010). The facility was studied for water quality treatment from February 2008 through December 2008. No flow data were collected from 1/21–3/5/2009 and 5/15–6/22/2009 due to equipment malfunction. The pond outlet is in the buffer area of wetland EC-3.

All six significant precipitation events (Table 4) occurred during the period of continuous flow monitoring at ECW1B1. Figure 1 shows that on four occasions during the 2007–2010 reporting period, the peak discharge exceeded the 2-year target flow of 0.54 cfs. For two of the events, no threshold criteria were exceeded.

- Event 1. The pond discharged in excess of the 10-year target during event 1. Peak pond discharge was 75% of the 100-year target flow. At the peak pond level, storage was at about 90% of the 100-year level, 60% of the total storage before overflow. The pond was functioning as designed.
- Event 2. The pond discharged above the 2-year target, but below the 10-year target. The average daily peak discharge for the period was 0.64 cfs, about 20% higher than the 2-year target. Pond discharge exceeded the threshold criteria during this period.
- Event 3. The pond discharged in excess of the 2-year target. Pond discharge exceeded the threshold criteria during this period.
- Event 4. The pond discharge approached but remained below the 2-year target flow rate and the pond was functioning as designed.

- Event 5. The pond peak pond discharge was 0.43 cfs, 80% of the 2-year target flow. The pond was functioning as designed during this period.
- Event 6. The pond was inspected following event 6 in December 2010, after continuous monitoring was complete. High water marks indicated the pond reached a water level of 483.4 feet with a corresponding discharge of 1.95 cfs, which is above the 10 year level but one foot below the 100 year level. The pond was functioning as designed.

Pond ECW1B1 discharges to wetland EC-3. Wetland levels frequently backed up into the energy dissipating outlet structure of the pond. We did not observe any erosion or channelized flow into the wetland during the reporting period 2007 – 2010.

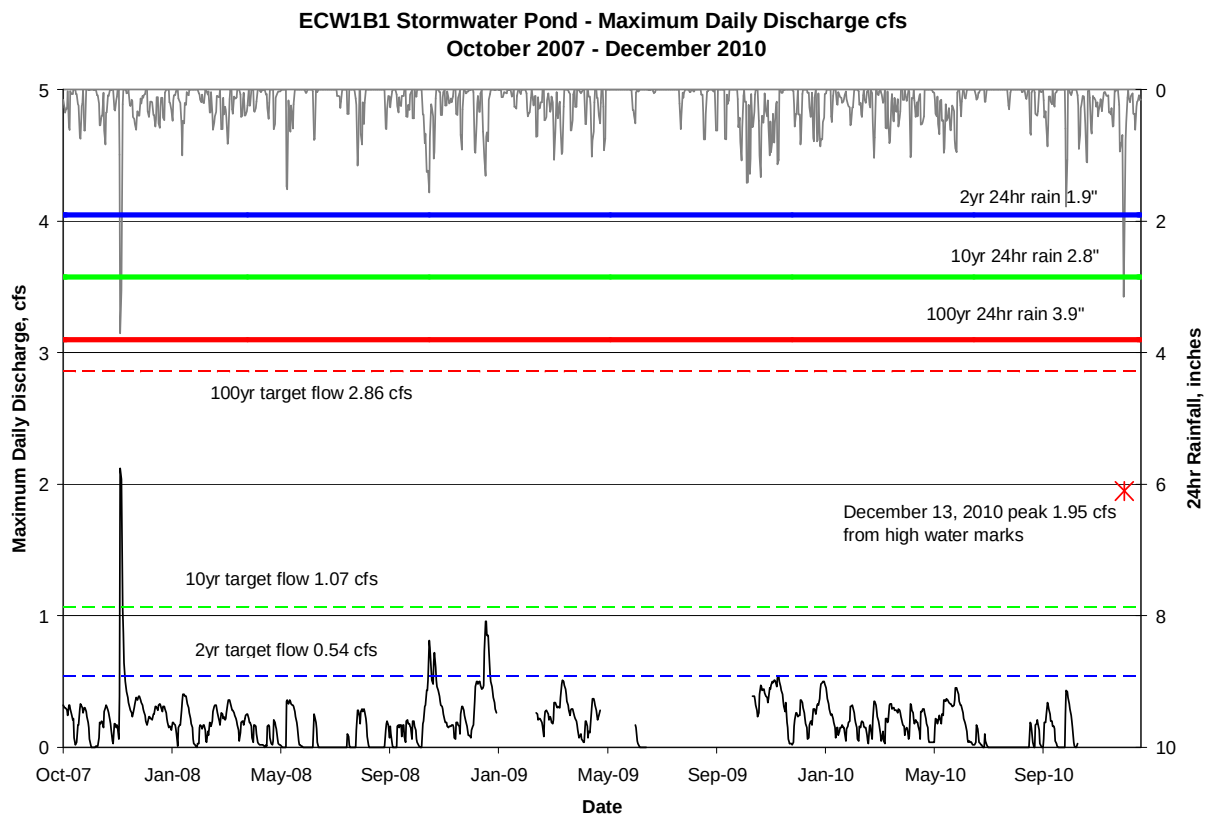


Figure 4. Maximum 24-hour discharge from stormwater pond ECW1B1 and 24-hour rainfall totals.

Peak release rates exceed the design target for the 2-year return storm more frequently than 24-hour rain intensity storms exceed the 2-year recurrence interval. The pond discharges in excess of the 2-year target flow after multiple days of relatively high intensity rain. Event 5, the isolated rain storm in October 2010 that was 95 percent of the 2-year 24-hour design storm resulted in a peak flow that was 80 percent of the 2-year target. Pond discharge in response to rain storms above the 10-year 24-hour intensity is as designed. Because the target flows are less than the modeled predevelopment flows, peak flow rates are similar or lower than the predevelopment conditions. The stormwater facility has never exceeded the 100-year release rate and overflow level since monitoring began in 2003.

The pond outlet control structure has three flow restrictors. The middle restrictor begins to discharge at the 2-year target 0.54 cfs. The lower restrictor could be reduced in size to reduce the flow rate to below the 2-year target for multiple day rain storms. This would reduce the total pond discharge rate and make less storage available for higher intensity storms resulting in a greater likelihood the pond discharge would exceed the 100-year target. KCWLRD monitoring of EC-3 wetland levels indicates that post-development water level fluctuations are consistent with those in a relatively undeveloped basin, although the mean water level in EC-3 appears to have increased to a new, but stable level (King County 2011a). Corrective action to lower some pond discharges to below the 2-year target flow while increasing the risk of flows at the 100-year or overflow rate is not warranted.

ECW3-1

Continuous water level monitoring commenced February 28, 2008. The facility was studied for water quality treatment from February 2008 through December 2008. No flow data were collected from 1/13–3/4/2009 and 4/28–10/28/2009 due to equipment malfunction. The pond discharges into wetland L/VS7. L/SV7 is a narrow wetland that flows from the north and crosses Redmond Ridge Drive north of pond ECW3-1 (W & H Pacific 2002). The discharge from the pond joins the wetland and proceeds out of the UPD into the lower EC-3 wetland complex to Rutherford Creek.

The retention/detention analysis and design included in the Technical Information Report (TIR) for the facility (W & H Pacific 2002) includes a letter of transmittal dated February 5, 2002 from Northwest Hydraulic Consultants (NHC) to W&H Pacific regarding the HSPF evaluation of ECW3-1 and the design specifications. The specifications differ from an earlier analysis in the TIR. The target flows listed in Table 4 are from the NHC design specifications.

Figure 5 shows that the daily peak flows from facility ECW3-1 exceeded the 2-year target flow of 0.62 cfs only in response to event 6. The estimated peak pond discharge of 1.0 cfs was less than the 10-year target. The outlet structure was examined for signs of erosion or concentrated flow. No erosion was observed. The leaf litter layer was intact and the only concentrated flow was from the wetland above the pond outlet.

Pond ECW3-1 appears to be performing as designed. No corrective actions are recommended. Analysis of the water quality treatment in the facility is discussed in another report (King County 2011b).

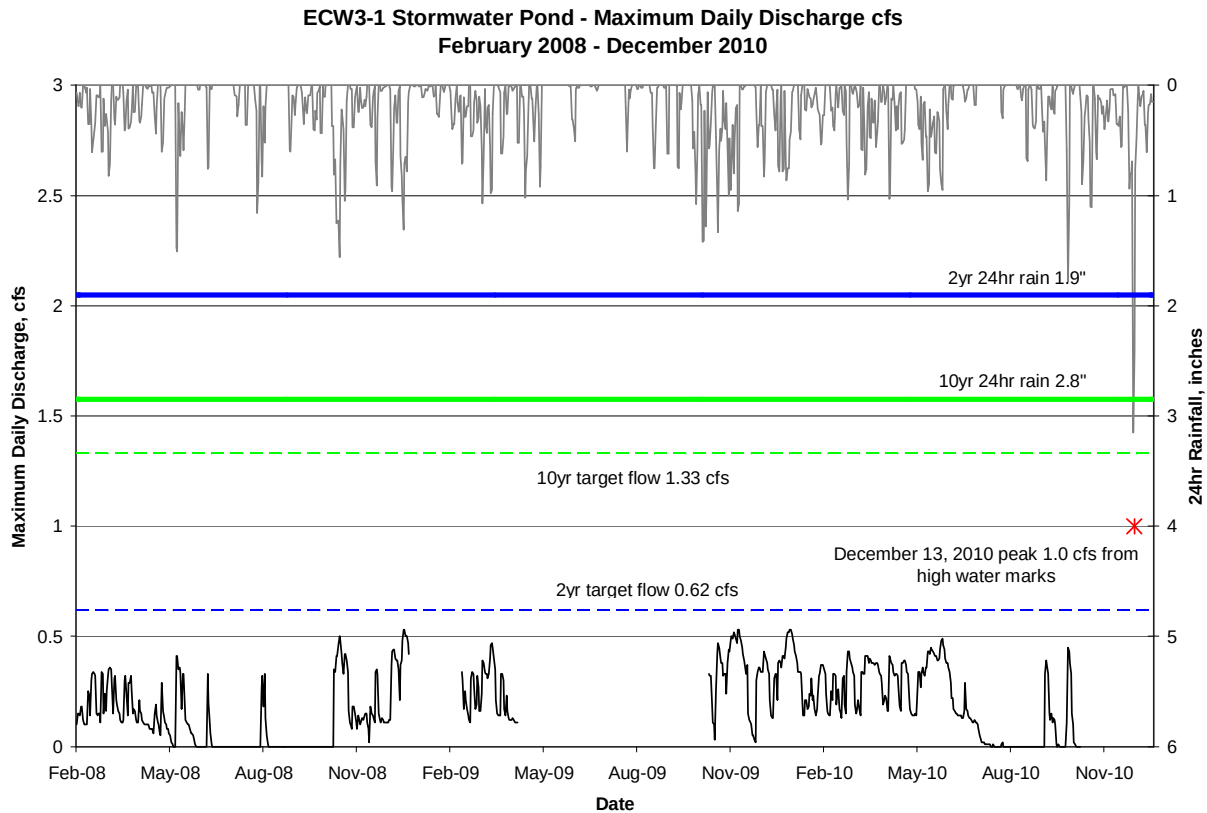


Figure 5. Maximum 24-hour discharge from stormwater pond ECW3-1 and 24-hour rainfall totals.

ECW2-1

Continuous water level monitoring of ECW2-1 commenced October 28, 2009 and was completed February 4, 2011. The pond discharges into wetland L/VS7. L/VS7 is a narrow wetland that flows from the north and crosses Redmond Ridge Drive north of pond ECW3-1 (W & H Pacific 2002). The discharge from the pond joins the wetland and proceeds out of the UPD into the lower EC-3 wetland complex to Rutherford Creek.

Figure 6 shows that during the 2009–2011 reporting period, the peak discharge exceeded the 2-year target flow of 0.22 cfs only following event 6. The peak flow was less than the 10-year target flow. The outlet structure to wetland L/VS7 was examined following event 6 for signs of erosion or concentrated flow. No erosion was observed.

Pond ECW2-1 appears to be performing as designed. No corrective actions are recommended.

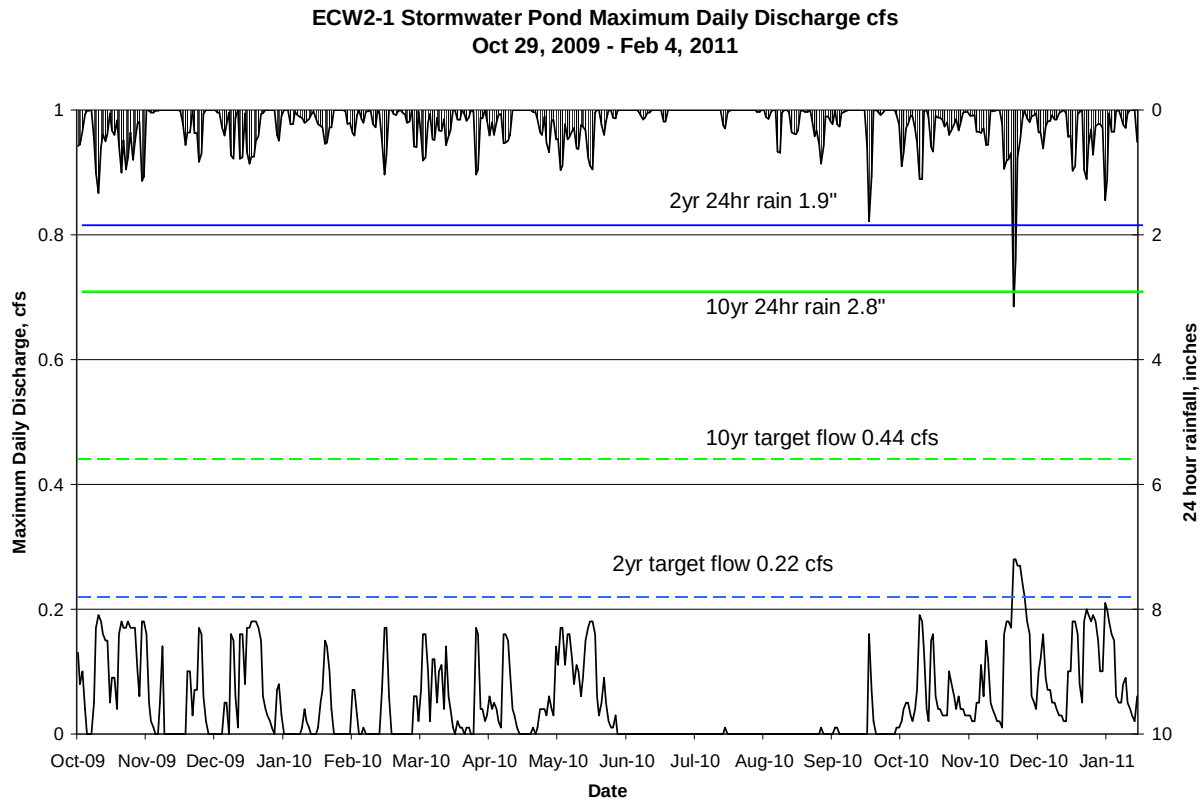


Figure 6. Maximum 24-hour discharge from stormwater pond EC2-1 and 24-hour rainfall totals.

NWD1-A

Continuous water level monitoring of Trilogy facility NWD1-A commenced October 28, 2009 and was completed October 22, 2011. The pond discharges into wetland BBC-26.

The retention/detention analysis and design for the facility is included in the Final Corrected TIR for Parcel H and F2 Redmond Ridge Division 6 (Triad Associates, 2006). The pond flow control configuration incorporates three restrictors to achieve flow duration targets into wetland BBC-26.

Figure 7 shows that the peak daily discharge did not exceed the target flows for event 5. The pond was inspected following event 6 after continuous monitoring was complete. High water marks indicated the pond reached a water level about 4.8 feet above the outlet with corresponding discharge of 0.5 cfs which is above the 2-year target but below the 10-year target flow rate of 0.68 cfs. The outlet structure was examined for signs of erosion or concentrated flow. No erosion was observed at the outlet structure.

Pond NWD1-A appears to be performing as designed. No corrective actions are recommended.

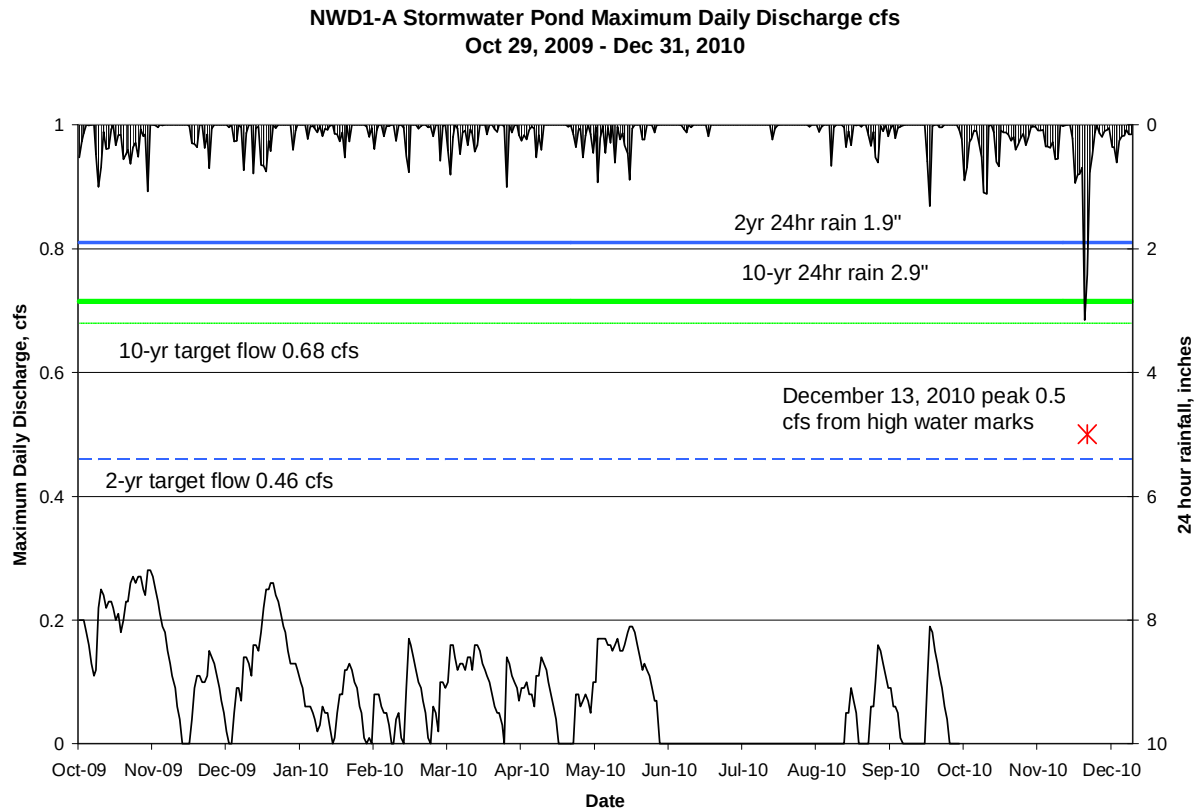


Figure 7. Maximum 24-hour discharge from stormwater pond NWD1-A and 24-hour rainfall totals.

Crest-stage

The five facilities monitored for overflow from 2008 through 2010 were BC2-1, ECW3-3, MC1-1, MC2-1, and MC4-1 (Figure 1). They were installed in 2001 and monitored bi-monthly starting January 6, 2003 for two years. Beginning in 2005 they were checked after significant rain storms or a minimum of twice a year. In addition, the ponds were examined after the December 2010 large rain storm. None of these stormwater facilities went into overflow during the monitoring period (Table 5). The stormwater pond levels were designed to remain below the overflow level unless the design storm was exceeded. This threshold was never exceeded for the five crest-stage gage monitored locations.

Table 5. 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 never went into overflow
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

3.3 Bypass Pipeline Monitoring

Gage 53F Wallace Creek Bypass Pipeline

Figure 8 shows that the Wallace bypass collected most of the peak storm flows and, in some cases, nearly all of the flow above baseflow. In the reporting period, the peak flow in the bypass gage was often over 10 cfs. The creek gage maximum instantaneous discharge was 5 cfs during the period. The analysis of stream hydrology in the Stream and Wetland Hydrologic Monitoring Assessment (King County 2011a) found that flows in Wallace Creek are consistent with those of a relatively undeveloped basin.

The Wallace Creek bypass pipeline system appears to be functioning correctly.

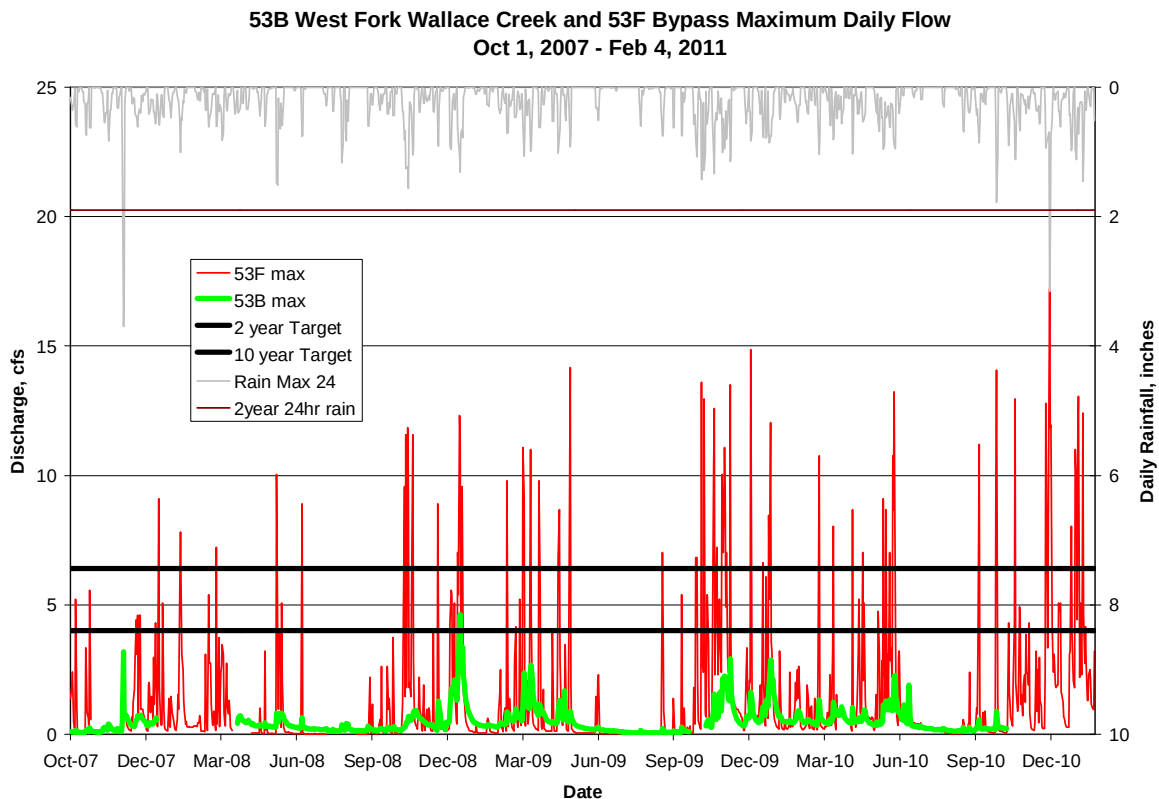


Figure 8. Maximum daily flow for Wallace Creek West (53B) and Wallace Creek bypass (53F), plus maximum daily rainfall.

Gage 53D Adair Creek Bypass Pipeline

The analysis of stream hydrology in the Stream and Wetland Hydrologic Monitoring Assessment (King County 2011a) found that while peak flows have not increased in Adair Creek there is some evidence of increased flow flashiness. The Adair bypass pipeline is intended to divert high flows out of the natural stream channel. Figure 9 shows that the bypass pipeline does divert some of the stormwater from the Adair Creek natural channel. As was found in the 2007 report (King County 2010), 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.

Based on the gage data for Adair Creek, the stormwater facilities diverting stormwater to the bypass pipeline are meeting the criteria for regulating peak flows, but based on the trend toward more flow flashiness, durations between half the 2-year return and the 10-year return flow may be greater than targets. The conclusion of the Stream Monitoring Assessment (King County 2011c) was that it does not appear that significant changes have occurred in the gaged stream channel cross sections or that shifts have occurred in the stream biological communities sampled in the vicinity of these gages that are consistent with the trends suggested in the Adair Creek flow data.

On April 28, 2010 a large flow resulting from a breached beaver dam that controlled the level of the NE basin wetland complex destroyed the stream gage 53A on Adair Creek, moved a great deal of sediment and greatly altered the channel. This event was not associated with any unusual rainfall. The stormwater controls in the Adair Creek basin were designed to keep all runoff out of the wetland. The bypass was not designed to protect the stream from an incident like this. None of the flow from this incident entered the bypass system. The bypass system was unaffected by the flow and continues to operate as before.

The Adair Creek bypass pipeline system correctly functions to limit peak stormwater flows in the natural stream channel. It may be that an insufficient amount of smaller stormflows are diverted into the pipeline. No evidence of degraded biological function was noted in the stream monitoring and therefore no corrective actions are advised.

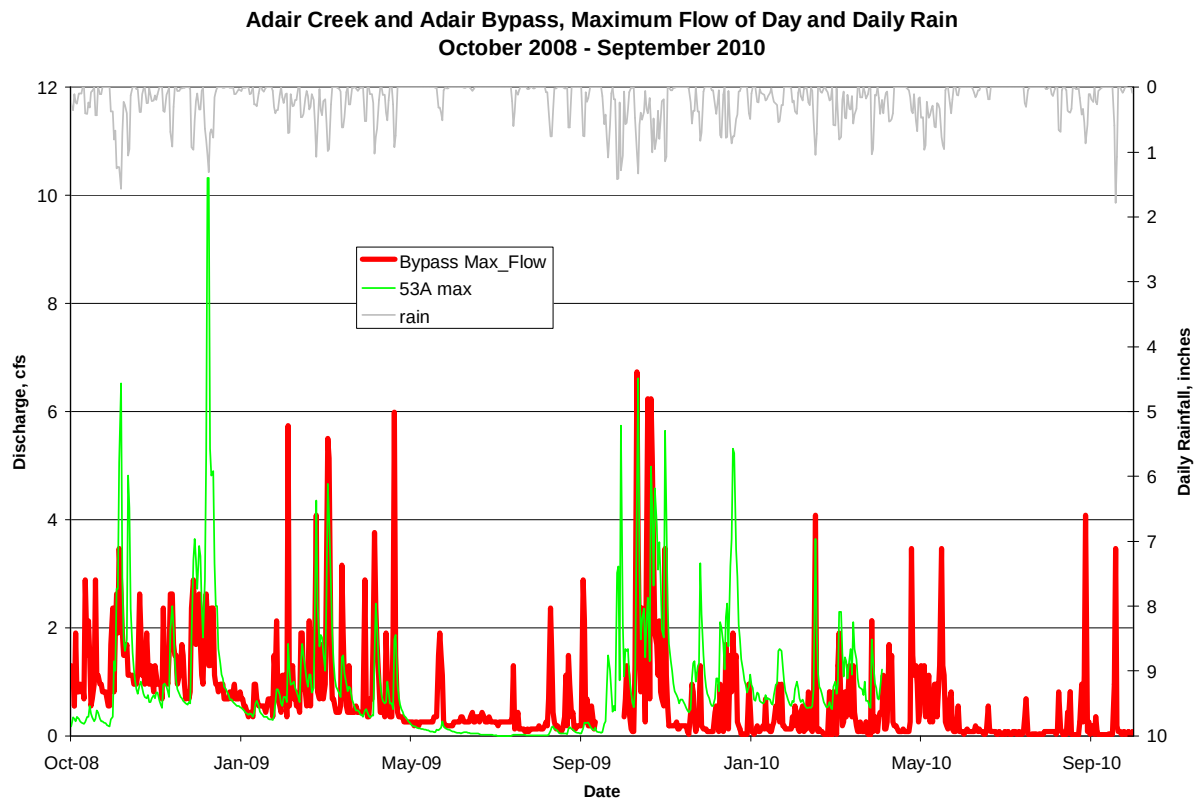


Figure 9. Maximum daily flow for Adair Creek (53A) and Adair Creek bypass (53D), plus maximum daily rainfall.

4.0 REFERENCES

- Hugh G. Goldsmith and Associates, I. 1996. Northridge UPD/FCC Urban Planned Development Master Drainage Plan (MDP). Prepared for Quadrant Corporations, Bellevue, Washington.
- Hartley, D. M. and D. E. Funke. 2001. Techniques for detecting hydrologic change in high resource streams. *Journal of the American Water Resources Association* 37:1589-1595.
- King County Department of Natural Resources and Parks. 1998. King County Washington, Surface Water Design Manual. Appendix D: Erosion and sediment control standards.
- King County. 1999. Redmond Ridge monitoring plan. King County, Department of Natural Resources, Water and Land Resources Division, Seattle, WA.
- King County. 2001. Post-development monitoring plan for the Trilogy at Redmond Ridge (formerly Blakely Ridge) Urban Planned Development (UPD). King County, Department of Natural Resources, Water and Land Resources Division, Seattle, Washington.
- King County. 2010. Trilogy and Redmond Ridge Urban Planned Development (UPD) Annual Monitoring Report: Water Year 2007. Prepared by Jo Wilhelm, Scott Stalnack, David Funke, and Ray Timm. Water and Land Resources Division, Seattle, Washington.
- King County. 2011a. Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Final Stream and Wetland Hydrologic Monitoring Assessment. Prepared by Curtis DeGasperi. Water and Land Resources Division, Seattle, Washington.
- King County. 2011b. 2008 Wet Weather Stormwater Facility Water Quality Monitoring at the Trilogy and Redmond Ridge Urban Planned Developments (UPDs). Prepared by Raymond Timm. Water and Land Resources Division, Seattle, Washington.
- King County. 2011c. Trilogy and Redmond Ridge Urban Planned Development (UPD) Monitoring Report: Biological, Physical, and Chemical Monitoring for Water Years 2008-2010. Prepared by Jo Wilhelm and Sally Abella. Water and Land Resources Division, Seattle, Washington.
- Northwest Engineering Company. 1995. Drainage Master Plan, Blakely Ridge UPD. Report number 598-03.00, prepared for Blakely Ridge Limited Partnership, Bellevue, Washington.
- Triad Associates. 2006. Trilogy at Redmond Ridge Parcels H and F2, Final Corrected Technical Information Report. Prepared for Trilogy at Redmond Ridge LLC.
- W & H Pacific. 2002. Final Corrected Technical Information Report (TIR) of Redmond Ridge Division 10 (formerly Parcels O and P Redmond Ridge South) for Quadrant Corporation. Bothell, Washington.

2008 Wet Weather Stormwater Facility Water Quality Monitoring at the Trilogy and Redmond Ridge Urban Planned Developments (UPDs), King County, Washington

Prepared by: Raymond Timm, Senior Scientist, King County Department of Natural Resources and Parks, Water and Land Resources Division. April 2011.



King County

Department of
Natural Resources and Parks

Water and Land Resources Division

201 South Jackson Street, Suite 600
Seattle, WA 98104

TABLE OF CONTENTS

1.0	Introduction.....	1
2.0	Methods	4
2.1	Redmond Ridge	4
2.2	Trilogy	6
3.0	Results and Discussion	6
3.1	Redmond Ridge	6
3.2	Trilogy	11
4.0	References	15
5.0	Appendices.....	17
	Appendix A. Washington State water quality standards for surface waters of the State.....	19
	Appendix B. Stormwater facility monitoring complete dataset for Redmond Ridge and Trilogy UPDs during 2008.....	21

TABLES

Table 1.	Stormwater facility, general and specific location of sampling, and development within which the facility is located.....	2
Table 2.	Effort, sampling methods, and parameters measured for stormwater facility water quality monitoring in the UPDs during 2008.....	4
Table 3.	Loadings and percent removal of select metals, nutrients, suspended solids, and fecal coliform bacteria during five storm events in 2008.	9
Table 4.	Concentrations of select analytes collected by grab sampling at the inlets and outlets of stormwater facilities in the Trilogy urban planned development (UPD) during 2008.....	13
Table B-1.	Stormwater facility water quality 2008 Redmond Ridge and Trilogy data.	21

FIGURES

Figure 1.	Location map of stormwater facilities monitored in the Trilogy and Redmond Ridge UPDs.....	3
Figure 2.	Schematic of flow-determined water quality sampling system.	6

1.0 INTRODUCTION

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 stormwater facility water quality monitoring conducted during storms that occurred in 2008. Storms were defined as wet weather events that exceeded 0.5 inches of rainfall following at least 48 hours of dry weather. The sampling and analysis methods follow recommendations specified in the original Redmond Ridge and Trilogy post-development monitoring plans (King County, 1999; King County 2001).

The UPD monitoring programs specified that the initiation and duration of stormwater facility monitoring was determined by 75 percent subbasin buildout (King County 1999; King County 2001). By the end of the 2008 water year, when this study was initiated, eight out of nine UPD subbasins had reached this threshold. Five stormwater facilities were monitored during this study that received surface stormwater from within these subbasins (Figure 1, Table 1).

The goal of the stormwater facility monitoring program was to determine removal efficiencies of common stormwater constituents. Many of the stormwater facility designs constructed at the UPDs were new and considered “experimental” because they were not explicitly approved in the King County Surface Water Design Manual (King County, 1998). The UPD stormwater facilities were designed according to strict permit requirements for the development and differed according to the master drainage plans for each respective development (King County 1999; King County 2001). In addition to water quality, the stormwater facilities monitoring program also evaluated whether stormwater facilities are working as designed with regard to hydrology and flow control objectives which will be addressed in a separate section of the 2008 monitoring report.

Table 1. Stormwater facility, general and specific location of sampling, and development within which the facility is located.

UPD	Name	Sampling Location	Dominant Land use	Construction Initiated	75% Buildout
Redmond Ridge	ECW 1b1 In	Inlet	Single Family Residential	1999	2003
Redmond Ridge	ECW 1b1 Out	Outlet		1999	2003
Redmond Ridge	ECW 3-1 Out	Outlet	Single Family Residential	1999	2003
Redmond Ridge	ECW3-1 In	Inlet		1999	2003
Trilogy	NED 9 In	Inlet	Attached Residential	2002	2007
Trilogy	NED 9 Out	Outlet		2002	2007
Trilogy	NWD 4 In	Inlet	Attached Residential	2003	2006
Trilogy	NWD 4 Out	Outlet	& Golf Course	2003	2006
Trilogy	SWD 3 Out*	Outlet	Attached Residential & Golf Course	2001	2005

*SWD 3 Out was only sampled at the facility outlet.

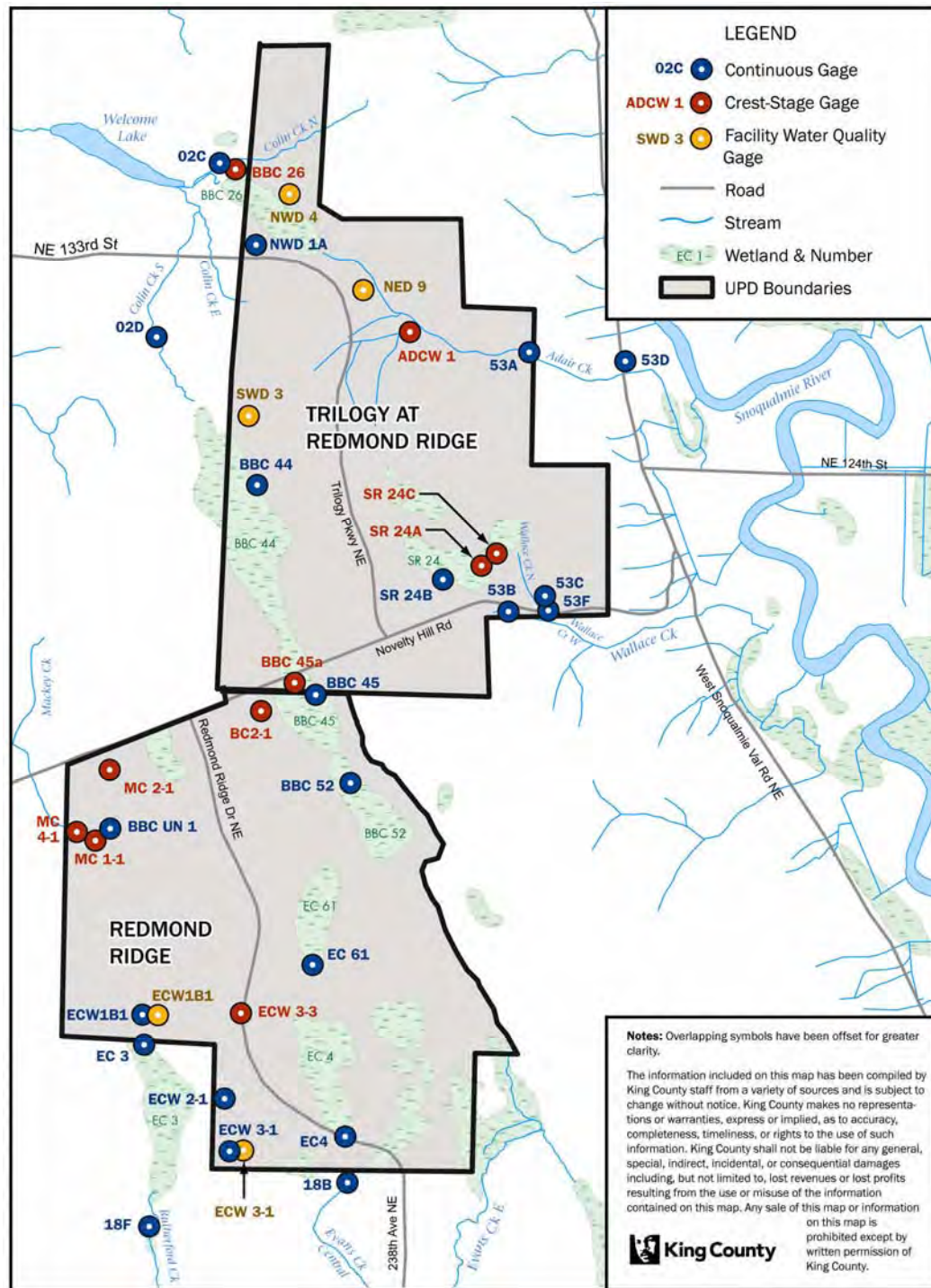


Figure 1. Location map of stormwater facilities monitored in the Trilogy and Redmond Ridge UPDs. Facilities monitored in this study were NWD 4, NED 9, and SWD 3 in Trilogy; and ECW 1B1, and ECW 3-1 in Redmond Ridge. The locations of these facilities are presented as gold dots in the map.

2.0 METHODS

The Trilogy and Redmond Ridge UPDs began as separate and unique developments and had specific monitoring plan requirements that identified respective threshold exceedance criteria to measure, among other things, the removal efficiencies of stormwater facilities (King County 1999; King County 2001). Due to differing requirements in the respective post-development monitoring plans, the sampling methods employed differed by development (Table 2).

Despite the dissimilarities between the monitoring requirements, in both UPDs, the monitoring studies targeted 80 percent removal efficiencies for total suspended solids (TSS), and 43 percent removal efficiencies for total phosphorus (TP). In addition, for other toxic water quality constituents, discharge concentrations were to remain below acute or chronic levels for aquatic biota or human health, pH was to remain between 6.5 and 8.5, and fecal coliform bacteria levels were to remain below a geometric mean of 50 colony forming units (cfu) per 100mL ($50\text{cfu}\cdot 100\text{mL}^{-1}$) with not more than 10 percent of all samples exceeding $100\text{cfu}\cdot 100\text{mL}^{-1}$ (King County, 1999; King County 2001). Washington State water quality standards for relevant acute and chronic concentrations are presented in Appendix A.

Table 2. Effort, sampling methods, and parameters measured for stormwater facility water quality monitoring in the UPDs during 2008.

Development SW Facility	Sampling Dates	When	Parameters
Trilogy Stormwater Facilities: NED09 NWD04 SWD03*	3/3/2008 5/20/2008 6/3/2008	3 wet season storms grab samples at facility inlet and outlet	pH, total N, total P, orthophosphate P, fecal coliform bacteria, hardness, total suspended solids, As, Cd, Ca, Cr, Cu, Pb, Mg, Mn, Ni, Ag, Zn
Redmond Ridge Stormwater Facilities: ECW01B ECW03	3/7/2008 5/13/2008 10/2/2008 11/6/2008 12/7/2008	Five wet season storms once monthly at 2 facilities. Samples were collected over multiple days until a 20 L composite bottle was filled. ISCO samplers were placed at inlet and outlet of each facility.	pH, total N, total P, orthophosphate P, fecal coliform bacteria, hardness, total suspended solids, As, Cd, Ca, Cr, Cu, Pb, Mg, Mn, Ni, Ag, Zn

*SWD03 was only sampled at the outlet because there were multiple inlets to that system.

2.1 Redmond Ridge

In Redmond Ridge, composite samplers were used to collect storm samples at the inflow and outflow structures of two facilities (ECW1B1, ECW3-1) in basins where construction was at least 75 percent complete (Table 2). The objective in the Redmond Ridge study was to estimate stormwater constituent loadings to receiving waters following Comings *et al.* (2000). Loadings

calculations require combining concentrations and flow to estimate quantities of contaminants being released to the environment. The event mean concentrations (EMC) of stormwater constituents are estimated as a function of concentration and discharge at the inflow and outflow locations. The difference between inflow and outflow EMC multiplied by flow, determines the loading to the receiving waters in units of mass per unit time (Horner et al. 1994). Loadings were estimated for analytes measured in units of $\mu\text{g}\cdot\text{L}^{-1}$, $\text{mg}\cdot\text{L}^{-1}$, and $\text{cfu}\cdot 100\text{ml}^{-1}$. An example of the dimensional analysis to convert units follows as equation 1.

$$Q \text{ cfs} = \frac{28.32\text{L}}{\text{cfs}} * \frac{X \mu\text{g}}{\text{L}} * \frac{1\text{kg}}{1,000,000,000\mu\text{g}} = \frac{Y \text{ kg}}{\text{event}} \dots\dots\dots (1)$$

Where: Q = measured discharge, 28.32 = the number of L in a cubic foot, X = the measured concentration in each sample ($\text{mg}\cdot\text{L}^{-1}$), and Y = the loadings estimate. Units cancel out and the result is reported in units of mass per storm event. Similar dimensional analysis was performed for analyte concentrations reported from the KCEL in units of $\text{mg}\cdot\text{L}^{-1}$, and $\text{cfu } 100\text{ml}^{-1}$. Loadings were calculated for the inflow and outflow of monitored stormwater facilities and respective values compared during storm events. Five storm event loadings estimates were averaged for inflows and outflows at both facilities to summarize facility performance for wet season months during 2008. This was a slight departure from the monitoring plan requirements (King County 2001) in that the plan called for a single wet season which is generally considered to begin on October 1 in western Washington.

Water quality parameters were measured once monthly during storms in the wet months of 2008, except for April when the storm definition was not met, and included total fractions of total suspended solids (TSS), Nitrogen, Phosphorus, Arsenic, Cadmium, Calcium, Chromium, Copper, Lead, Magnesium, Manganese, Nickel, Silver, Zinc, Hardness, pH, and Fecal Coliform bacteria. These analytes were all collected with Teledyne ISCO automated composite samplers that ran for 5 days once triggered except for pH and fecal coliform bacteria which were collected in grab samples at the end of storms due to laboratory holding time limitations (King County, 2002). Sampled storm events occurred during March, May, October, November, and December of 2008.

The samples were collected using ISCO 4230 bubbler flow meters and ISCO 3700 automatic samplers (0). The flow meters measured water level behind a hydraulic control (inlet pipe or outlet multiple orifice control structure) and were programmed with stage – discharge rating tables for each location. Flows were determined by measuring stage for 15 seconds and comparing that value to the corresponding flow from existing rating tables for pipes. This value was aggregated for the storm event and stored as the total accumulated flow. For each sampling event, storm total rainfall was predicted and used to estimate the potential runoff for each inlet. Flow meters were programmed to send a signal to the automatic sampler every “x” units of flow where x was the estimated potential inflow divided by 100, to yield 100 samples for the storm. To guard against false starts, each flow meter was programmed to begin sampling only after an expected rate of change in water level condition was met. The flow meters recorded the time each signal was sent to the sampler, and the water level and average flow for each 15 minute period. The composite samples were collected by taking 150 ml samples during the storm event so that 100 samples would fill a 20 liter composite sample bottle.

2.2 Trilogy

At the Trilogy UPD, sampling was limited to three wet season storms. The King County Environmental Laboratory provided clean sample bottles for each event. The objective of this study was to quantify the difference between inflow and outflow concentrations of select stormwater contaminants. Samples were collected at the inflow and outflow structures of stormwater facilities * (0, 0) by dipping clean sample bottles into the collection locations, fixed or filtered in the field where appropriate, stored on ice in the dark, and transported to the lab for analysis of important nutrients, hardness, suspended solids, and routine metals (0). Measures of pH were obtained in the field. Sampled storm events occurred during March, May, and June 2008. In all cases at both UPDs, metal analysis was performed using inductively coupled plasma mass spectrometry (ICP-MS) methods.

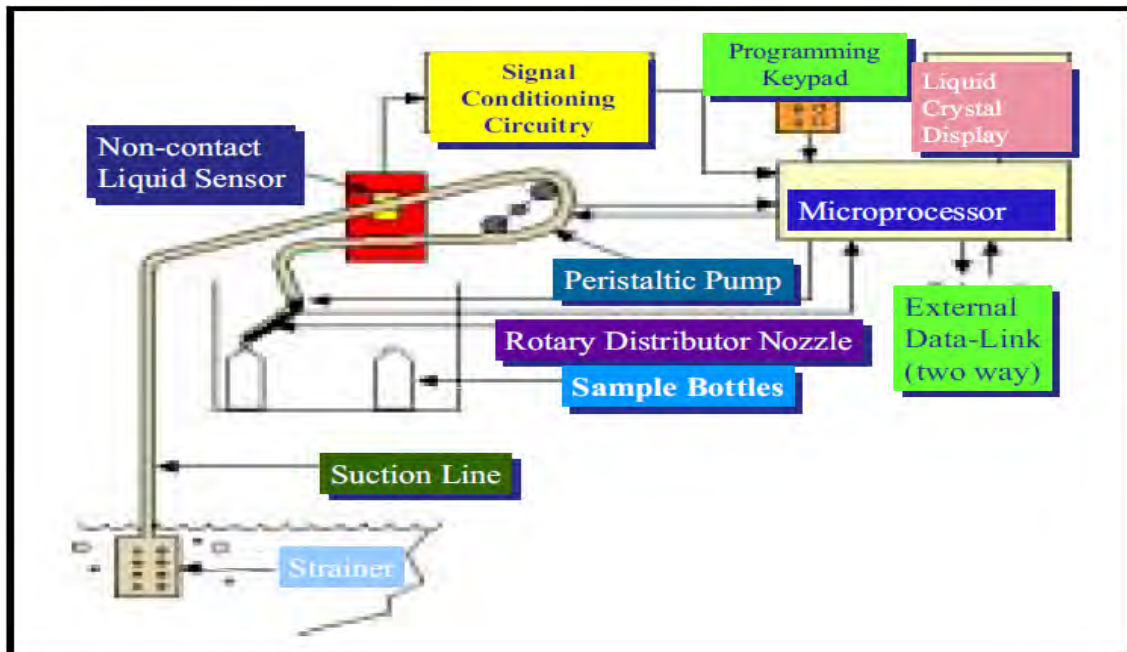


Figure 2. Schematic of flow-determined water quality sampling system.

When discharge threshold value is reached, the pump draws an aliquot from the target system and places it in a sample bottle. When the sample is complete, the bottles rotate in preparation for the next aliquot until the entire composite sample is collected. Graphic Source: (Teledyne ISCO, 2008).

3.0 RESULTS AND DISCUSSION

3.1 Redmond Ridge

Composite water quality samples were taken during storms that occurred approximately monthly during the wet season on: March 7, 2008; May 13, 2008; October 2, 2008; November 6, 2008; and December 7, 2008 (0). Sampling occurred at the inflow and outflow pipes of stormwater facilities; ECW 1B1, and ECW 3-1 (Figure 1) to estimate loadings reductions for each facility.

Twelve trace metals, as well as hardness, total Nitrogen (total N), total Phosphorous (total P), and TSS were collected in each composite sample. Fecal coliform bacteria and pH (lab and field) samples were collected as grab samples at the end of the composite sampling period.

For all analytes except fecal coliform bacteria, stormwater facility ECW 1B1 reduced loadings to the environment on a five-storm averaged basis (Table 3). Specifically, the Redmond Ridge monitoring plan called for a 43 percent reduction in total P, and an 80 percent reduction in TSS. These targets were met in this facility with averaged reductions of 86 percent and 88 percent respectively for total P. In addition, reductions of trace metals loadings ranged from less than 11 percent to more than 84 percent; and total N loadings were reduced by nearly 77 percent (Table 3). Furthermore, there were no measured exceedances for acute or chronic water quality standards (WAC 173-201A, 2006) in the outflowing pond discharge (Appendix B).

Toxicity estimates were derived from total metals samples as per the UPD monitoring plan requirements (King County 2001). These were conservative estimates of toxicity because the State of Washington primarily determines toxicity for the dissolved fraction of trace metals and adjusts for the water hardness at the time a sample is collected. The complete list of water quality measurements can be found in Appendix B.

In general, the reported reductions in loadings are conservative because loadings are related to both concentration and discharge (see equation 1). In particular, precision in discharge estimates decreases dramatically as flows get very small. For example, in stormwater facility ECW 1B1, the average discharge flowing into the pond during all storms was 0.6 cubic feet per second (cfs), while the average outflowing discharge was 0.9 cfs. These measurements are collected as depth of water above a pressure transducer and then discharge is derived from a table for pipe hydraulics. That depth measurement is subject to variability from a number of sources that may include turbulence in the pipe, the length of pipe, the pipe gradient, as well as water temperature and viscosity (Adrien, 2004). At very small discharges the error on the measurement can be larger than the estimated discharge value. Since loadings estimates are a function of discharge, errors in the discharge calculations can substantially alter the precision of estimated loadings values (Horner et al., 1994).

In addition, the loadings reduction targets established in the monitoring plans are predicated on sampling the same water mass as it enters the stormwater facility and as it leaves. However, water does not move through a stormwater facility as a homogeneous mass (Ward and Trimble 2004). Instead, stormwater treatment occurs along a continuum of flow path and duration that is intended to change the water as it moves through the system. In an absolute sense, the measured concentrations are generally very low and not of concern relative to State of Washington water quality standards, even if percent loadings reductions targets are not met for a given storm reported here.

Table 3. Loadings and percent removal of select metals, nutrients, suspended solids, and fecal coliform bacteria during five storm events in 2008. Two stormwater facilities were monitored in the Redmond Ridge urban planned development (UPD). Values represent inflow and outflow loadings for each analyte, and the percent removal when the outflow loadings were compared to inflow loadings. Loadings values and percent removal efficiencies were averaged across all five storms and presented at the bottom of each stormwater facility in the table.

SW Facility	Storm Date	Chromium*		Copper*		Lead*		Zinc*		Fecal Coliform [‡]		Tot. Susp. Solids*		Tot. Phosphorus*		Tot. Nitrogen*	
		Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
ECW 1B1	Mar-08	0.001	0.001	0.004	0.004	0.001	0.000	0.013	0.006	NA	NA	13.932	2.021	0.194	0.032	2.282	0.624
	% Removal	-40		-82		-55		-55		NA		-85		-84		-73	
	May-08	0.001	0.000	0.003	0.004	0.001	0.000	0.011	0.005	23.3 x 10 ⁶	0.000	11.812	1.780	0.165	0.028	1.935	0.550
	% Removal	-38		9		-81		-53		-100		-85		-83		-72	
	Oct-08	0.001	0.001	0.006	0.005	0.002	0.000	0.018	0.006	14.4x10 ⁷	42.2x10 ⁶	19.925	2.253	0.278	0.036	3.264	0.696
	% Removal	-53		-18		-86		-65		-71		-89		-87		-79	
	Nov-08	0.007	0.002	0.035	0.019	0.012	0.001	0.110	0.026	31.2x10 ⁷	10.6x10 ⁸	118.910	8.975	1.658	0.142	19.479	2.771
	% Removal	-69		-45		-90		-77		240		-92		-91		-86	
	Dec-08	0.001	0.001	0.005	0.005	0.002	0.000	0.016	0.007	23.0x10 ⁶	14.5x10 ⁶	17.492	2.329	0.244	0.037	2.865	0.719
	% Removal	-45		-4		-83		-59		-37		-87		-85		-75	
Annual Average Loadings		0.002	0.001	0.011	0.007	0.004	0.000	0.034	0.010	12.6x10 ⁷	28.1x10 ⁷	36.414	3.472	0.508	0.055	5.965	1.072
% Removal Efficiency		-49		-11		-84		-62		8		-88		-86		-77	
ECW 3-1	Mar-08	0.001	0.001	0.004	0.006	0.000	0.000	0.011	0.004	88.7x10 ⁶	54.0x10 ⁶	20.521	14.400	0.438	0.067	4.003	0.850
	% Removal	28		45		-11		-65		-39		-30		-85		-79	
	May-08	0.001	0.001	0.002	0.004	0.000	0.000	0.002	0.002	29.2x10 ⁶	16.2x10 ⁶	1.684	6.160	0.026	0.032	0.636	0.681
	% Removal	-0.3		146		121		1		-45		266		22		7	
	10/1/2008 [‡]	0.001	NA	0.005	NA	0.001	NA	0.012	NA	91.1x10 ⁷	NA	13.738	NA	0.082	NA	0.805	NA
	% Removal	NA		NA		NA		NA		NA		NA		NA		NA	
	Nov-08	0.002	0.002	0.013	0.012	0.002	0.002	0.027	0.020	19.1x10 ⁸	79.2x10 ⁸	8.186	11.671	0.198	0.189	3.602	3.193
	% Removal	5		-6		0.2		-25		315		43		-4		-11	
	Dec-08	0.001	0.000	0.007	0.004	0.001	0.000	0.041	0.007	97.9x10 ⁵	40.5x10 ⁶	27.706	7.092	0.108	0.041	0.936	0.575
	% Removal	-65		-39		-85		-83		314		-74		-62		-39	
Annual Average Loadings		0.772	0.313	3.681	2.414	0.571	0.186	13.196	3.203	17.7x10 ⁶	13.5x10 ⁶	14.204	7.000	0.147	0.043	1.536	0.651
% Removal Efficiency		-8		36		6		-43		136		51		-32		-30	

* Loadings calculated as Kg/ event
[‡] Loadings calculated as cfu/ event
[‡] October 2008 Storm did not generate outflow in SW Facility ECW 3-1

3.2 Trilogy

Three stormwater facilities were monitored during this study to measure removal efficiencies of stormwater pollutants. Two of the facilities (NED 09, and NED 04) were sampled at a single inflow and single outflow location in order to estimate percent reductions in stormwater constituents. Stormwater facility SWD 03 received multiple inputs from a golf course fairway, but had a single outflow facility that discharged to a forest that is contiguous with a bog wetlands system. We sampled SWD 03 only in the single outflow structure to quantify pollutant concentrations leaving that facility.

With the exception of chromium, metals concentrations were generally very low in all facilities across all storm events. However, total metals concentrations of copper, lead, and zinc entering stormwater facilities NED 09 and NED 04 were high enough to exceed State of Washington water quality standards for “chronic” or “acute” thresholds for aquatic life (WAC 173-201A, 2006) (Table 4). However, only total zinc exceeded “acute” water quality standards in water leaving stormwater facility NED 09. Concentrations during the May 20 and June 3 events were quite high and could be related to stormwater system maintenance that occurred during that period (McDonald, 2011). While designed holding times of facilities may not facilitate a chronic exposure, the exceedance of a state water quality threshold is notable. Therefore those instances and concentrations were called out in the table.

Similar to the stormwater monitoring in Redmond Ridge, the measurements taken in the Trilogy stormwater facilities are subject to sources of error that make direct comparisons of influent and effluent water unlikely. Stormwater facility designs ensure that water stays in a given pond for several days in order for treatment to occur. Our study was designed so that grab samples were taken at inflow and outflow structures on the same day at the onset of storms. In hind sight, that did not allow for measurement of contaminants in the same water mass. However, we were able to characterize the contaminant levels of stormwater as respective facility hydrographs were rising and discharging treated stormwater to the environment (Comings et al., 2000).

Irrespective of the flaws in study design, absolute concentrations in treated waters in monitored stormwater facilities at both UPDs generally had lower concentrations of pollutants than inflowing water from the managed landscapes that drained to them. In general, it appears water quality improves during treatment in stormwater facilities located in both UPDs. Additionally, important information has been gained regarding appropriate ways to measure the performance of these facilities as relates to water quality.

Table 4. Concentrations of select analytes collected by grab sampling at the inlets and outlets of stormwater facilities in the Trilogy urban planned development (UPD) during 2008. Facilities NED 09 and NWD 04 were sampled at inlet and outlet structures. Differences in concentrations were calculated between incoming and outgoing water to estimate pollutant removal efficiency. The presence of multiple inflow structures relegated sampling in SWD 03 at the single outlet structure. Yellow highlights indicate exceedance of Washington "chronic" water quality standards. Red highlights indicate exceedance of Washington "acute" water quality standards. Note that concentrations were analyzed as total concentrations and water quality standards are for dissolved fractions only. Values below method detection limits are represented as "<MDL".

Stormwater Facility	Storm Date	Chromium*		Copper*		Lead*		Zinc*		Fecal Coliform [¥]		Tot. Susp. Solids [§]		Tot. Phosphorus [§]		Tot. Nitrogen [§]	
		Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
NED 09	3/11/2008	0.84	0.62	4.22	2.87	1.22	0.8	8.28	5.41	9	25	15.3	4.95	0.0355	0.025	1.02	0.489
	% Difference	-26		-32		-34		-35		178		-68		-30		-52	
	5/20/2008	0.81	<MDL	5.88	2.55	1.01	<MDL	421.00	86.30	2700.00	120.00	5.31	1.00	0.07	0.03	0.99	0.46
	% Difference	-100		-57		-100		-80		-96		-81		-65		-54	
	6/3/2008	1.20	<MDL	7.12	2.16	1.76	<MDL	59.90	313.00	560.00	10.00	6.67	4.05	0.05	0.05	0.61	0.62
	% Difference	-100		-70		-100		423		-98		-39		8		2	
	Annual Average % Difference	-75.40		-52.76		-78		103		-5		-63		-29		-35	
NWD 04	3/11/2008	0.82	<MDL	5.69	1.60	0.32	<MDL	5.68	0.66	3.00	4.00	2.30	0.70	0.03	0.01	0.95	0.24
	% Difference	-100		-72		-100		-89		33		-70		-60		-75	
	5/20/2008	0.95	<MDL	6.56	3.08	0.42	<MDL	4.81	1.00	3200.00	16.00	4.04	1.91	0.08	0.03	1.56	0.37
	% Difference	-100		-53		-100		-79		-100		-53		-68		-76	
	6/3/2008	0.53	<MDL	4.72	2.84	0.39	<MDL	3.90	0.93	2900.00	13.00	2.75	1.30	0.10	0.04	1.07	0.55
	% Difference	-100		-40		-100		-76		-100		-53		-59		-48	
	Annual Average % Difference	-100		-55		-100		-81		-55		-58		-62		-66	
SWD 03	3/11/2008		0.41		5.18		0.24		4.34		3.00		3.03		0.04		0.71
	5/20/2008				3.77				3.70		580.00		4.17		0.10		1.28
	6/3/2008				2.31				2.00		2500.00		4.40		0.14		1.07

* concentrations presented as $\mu\text{g}\cdot\text{L}^{-1}$

¥ concentrations presented as colony forming units (CFU)·100ml⁻¹

§ concentrations presented as $\text{mg}\cdot\text{L}^{-1}$

4.0 REFERENCES

- Adrien, N. G. (2004). *Computational Hydraulics and Hydrology: An Illustrated Dictionary*. Boca Raton, London, New York, Washington, D.C.: CRC Press.
- Comings, K. J., Booth, D. B., & Horner, R. R. (2000). Storm water pollutant removal by two wet ponds in Bellevue, Washington. *Journal of Environmental Engineering*, 126(4), 321-330.
- Horner, R. R., Skupien, J. J., Livingston, E. H., & Shaver, H. E. (1994). *Fundamentals of urban runoff management: technical and institutional issues*. Washington, DC: Terrene Institute.
- King County. (1998). *King County Surface Water Design Manual*. Seattle, WA: Department of Natural Resources.
- King County. (1999). *Redmond Ridge monitoring plan*. Seattle, WA: King County, Department of Natural Resources, Water and Land Resources Division.
- King County. (2001). *Post-development monitoring plan for the Trilogy at Redmond Ridge (formerly Blakely Ridge) Urban Planned Development (UPD)*. Seattle, Washington: King County, Department of Natural Resources, Water and Land Resources Division.
- King County. (2002). *Sampling and analysis plan: Ambient streams and rivers routine monitoring, ambient streams and rivers wet weather monitoring, and SWAMP streams and rivers trace metals and organics monitoring*. Seattle, Washington: Prepared by Bob Kruger, King County Environmental Laboratory, King County Water and Land Resources Division.
- McDonald, A. (2011). Personal communication, January 2011. Seattle, WA.
- Teledyne ISCO. (2008). *Stormwater monitoring guide: Watersheds, TMDLs, industrial sites*. Lincoln, Nebraska.
- Ward, A. D., and S.W. Trimble. (2004). *Environmental Hydrology (2nd Edition)*. Boca Raton, FL: CRC Press.
- Washington Administrative Code. (2006). *Water quality standards for surface waters of the State of Washington*, Chapter 173-201A

5.0 APPENDICES

Appendix A. Washington State water quality standards for surface waters of the State

WAC 173-201A-240

Toxic substances.

(1) Toxic substances shall not be introduced above natural background levels in waters of the state which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department.

(2) The department shall employ or require chemical testing, acute and chronic toxicity testing, and biological assessments, as appropriate, to evaluate compliance with subsection (1) of this section and to ensure that aquatic communities and the existing and characteristic beneficial uses of waters are being fully protected.

(3) The following criteria, found in Table 240(3), shall be applied to all surface waters of the state of Washington for the protection of aquatic life. The department may revise the following criteria on a statewide or water body-specific basis as needed to protect aquatic life occurring in waters of the state and to increase the technical accuracy of the criteria being applied. The department shall formally adopt any appropriate revised criteria as part of this chapter in accordance with the provisions established in chapter 34.05 RCW, the Administrative Procedure Act. The department shall ensure there are early opportunities for public review and comment on proposals to develop revised criteria. Values are µg/L for all substances except Ammonia and Chloride which are mg•L⁻¹:

Table 240(3)
Toxics Substances Criteria

Substance	Freshwater		Marine Water	
	Acute	Chronic	Acute	Chronic
Arsenic ^o	360.0b	190.0c	69.0b	36.0c,n
Cadmium ^o	d,b	e,c	42.0b	9.3c
Chromium (Hex) ^o	15.0b,f,u	10.0c,v	1,100.0b,f	50.0c
Chromium (Tri) ^z	g,b	h,c	—	—
Copper ^o	i,b	k,c	4.8b	3.1c
Lead ^o	q,b	r,c	210.0b	8.1c
Nickel ^o	t,b	p,c	—	74.0b
Silver ^o	y,a	-	1.9a	—
Zinc ^o	l,b	m,c	90.0b	81.0c

Notes to Table 240(3):

- An instantaneous concentration not to be exceeded at any time.
- A 1-hour average concentration not to be exceeded more than once every three years on the average.
- A 4-day average concentration not to be exceeded more than once every three years on the average.
- $\leq (0.944)(e(1.128[\ln(\text{hardness})]-3.828))$ at hardness = 100. Conversion factor (CF) of 0.944 is hardness dependent. CF is calculated for other hardnesses as follows: $CF = 1.136672 - [(\ln \text{ hardness})(0.041838)]$.

- e. $\leq (0.909)(e^{(0.7852[\ln(\text{hardness})] - 3.490)})$ at hardness = 100. Conversion factor (CF) of 0.909 is hardness dependent. CF is calculated for other hardnesses as follows: $CF = 1.101672 - [(\ln \text{ hardness})(0.041838)]$.
- f. Salinity dependent effects. At low salinity the 1-hour average may not be sufficiently protective.
- g. $\leq (0.316)e^{(0.8190[\ln(\text{hardness})] + 3.688)}$
- h. $\leq (0.860)e^{(0.8190[\ln(\text{hardness})] + 1.561)}$
- i. $\leq (0.960)(e^{(0.9422[\ln(\text{hardness})] - 1.464)})$
- k. $\leq (0.960)(e^{(0.8545[\ln(\text{hardness})] - 1.465)})$
- l. $\leq (0.978)(e^{(0.8473[\ln(\text{hardness})] + 0.8604)})$
- m. $\leq (0.986)(e^{(0.8473[\ln(\text{hardness})] + 0.7614)})$
- n. Nonlethal effects (growth, C-14 uptake, and chlorophyll production) to diatoms (*Thalassiosira aestivalis* and *Skeletonema costatum*) which are common to Washington's waters have been noted at levels below the established criteria. The importance of these effects to the diatom populations and the aquatic system is sufficiently in question to persuade the state to adopt the USEPA National Criteria value (36 µg/L) as the state threshold criteria, however, wherever practical the ambient concentrations should not be allowed to exceed a chronic marine concentration of 21 µg/L.
- o. These ambient criteria in the table are for the dissolved fraction. The cyanide criteria are based on the weak acid dissociable method. The metals criteria may not be used to calculate total recoverable effluent limits unless the seasonal partitioning of the dissolved to total metals in the ambient water are known. When this information is absent, these metals criteria shall be applied as total recoverable values, determined by back-calculation, using the conversion factors incorporated in the criterion equations. Metals criteria may be adjusted on a site-specific basis when data are made available to the department clearly demonstrating the effective use of the water effects ratio approach established by USEPA, as generally guided by the procedures in USEPA Water Quality Standards Handbook, December 1983, as supplemented or replaced by USEPA or ecology. Information which is used to develop effluent limits based on applying metals partitioning studies or the water effects ratio approach shall be identified in the permit fact sheet developed pursuant to WAC [173-220-060](#) or [173-226-110](#), as appropriate, and shall be made available for the public comment period required pursuant to WAC [173-220-050](#) or [173-226-130](#)(3), as appropriate. Ecology has developed supplemental guidance for conducting water effect ratio studies.
- p. $\leq (0.997)(e^{(0.8460[\ln(\text{hardness})] + 1.1645)})$
- q. $\leq (0.791)(e^{(1.273[\ln(\text{hardness})] - 1.460)})$ at hardness = 100. Conversion factor (CF) of 0.791 is hardness dependent. CF is calculated for other hardnesses as follows: $CF = 1.46203 - [(\ln \text{ hardness})(0.145712)]$.
- r. $\leq (0.791)(e^{(1.273[\ln(\text{hardness})] - 4.705)})$ at hardness = 100. Conversion factor (CF) of 0.791 is hardness dependent. CF is calculated for other hardnesses as follows: $CF = 1.46203 - [(\ln \text{ hardness})(0.145712)]$.
- t. $\leq (0.998)(e^{(0.8460[\ln(\text{hardness})] + 3.3612)})$
 $\leq (0.998)(e^{(0.8460[\ln(\text{hardness})] + 3.3612)})$
- u. The conversion factor used to calculate the dissolved metal concentration was 0.982.
- v. The conversion factor used to calculate the dissolved metal concentration was 0.962.
- y. $\leq (0.85)(e^{(1.72[\ln(\text{hardness})] - 6.52)})$
- z. Where methods to measure trivalent chromium are unavailable, these criteria are to be represented by total-recoverable chromium.

[Statutory Authority: RCW [90.48.035](#). 06-23-117 (Order 06-04), § 173-201A-240, filed 11/20/06, effective 12/21/06. Statutory Authority: Chapters [90.48](#) and [90.54](#) RCW. 03-14-129 (Order 02-14), amended and recodified as § 173-201A-240, filed 7/1/03, effective 8/1/03. Statutory Authority: Chapter [90.48](#) RCW and 40 CFR 131. 97-23-064 (Order 94-19), § 173-201A-040, filed 11/18/97, effective 12/19/97. Statutory Authority: Chapter [90.48](#) RCW. 92-24-037 (Order 92-29), § 173-201A-040, filed 11/25/92, effective 12/26/92.]

Appendix B. Stormwater facility monitoring complete dataset for Redmond Ridge and Trilogy UPDs during 2008.

Table B-1. Stormwater facility water quality 2008 Redmond Ridge and Trilogy data.

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
NED09IN	3/11/2008 11:00	Arsenic, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.5	2.5
NED09IN	3/11/2008 11:00	Cadmium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.1	0.5
NED09IN	3/11/2008 11:00	Calcium, Total, ICP-MS	11100	$\mu\text{g}\cdot\text{L}^{-1}$		50	250
NED09IN	3/11/2008 11:00	Chromium, Total, ICP-MS	0.84	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.4	2
NED09IN	3/11/2008 11:00	Copper, Total, ICP-MS	4.22	$\mu\text{g}\cdot\text{L}^{-1}$		0.4	2
NED09IN	3/11/2008 11:00	Fecal Coliform	9	$\text{CFU}\cdot 100\text{ml}^{-1}$			
NED09IN	3/11/2008 11:00	Hardness, Calc	39.9	$\text{CaCO}_3\cdot\text{L}^{-1}$		0.2	1.25
NED09IN	3/11/2008 11:00	Lead, Total, ICP-MS	1.22	$\mu\text{g}\cdot\text{L}^{-1}$		0.2	1
NED09IN	3/11/2008 11:00	Magnesium, Total, ICP-MS	2970	$\mu\text{g}\cdot\text{L}^{-1}$		30	150
NED09IN	3/11/2008 11:00	Manganese, Total, ICP-MS	24.3	$\mu\text{g}\cdot\text{L}^{-1}$		0.2	1
NED09IN	3/11/2008 11:00	Nickel, Total, ICP-MS	1.1	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.3	1.5
NED09IN	3/11/2008 11:00	Orthophosphate Phosphorus	0.018	$\text{mg}\cdot\text{L}^{-1}$		0.002	0.005
NED09IN	3/11/2008 11:00	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
NED09IN	3/11/2008 11:00	Total Nitrogen	1.02	$\text{mg}\cdot\text{L}^{-1}$		0.05	0.1
NED09IN	3/11/2008 11:00	Total Phosphorus	0.0355	$\text{mg}\cdot\text{L}^{-1}$		0.005	0.01
NED09IN	3/11/2008 11:00	Total Suspended Solids	15.3	$\text{mg}\cdot\text{L}^{-1}$		0.6	1.1
NED09IN	3/11/2008 11:00	Zinc, Total, ICP-MS	8.28	$\mu\text{g}\cdot\text{L}^{-1}$		0.5	2.5
NED09IN	3/11/2008 11:00	pH	7.13	pH	H		
NED09IN	5/20/2008 13:05	Arsenic, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.5	2.5
NED09IN	5/20/2008 13:05	Cadmium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.1	0.5
NED09IN	5/20/2008 13:05	Calcium, Total, ICP-MS	11000	$\mu\text{g}\cdot\text{L}^{-1}$		50	250
NED09IN	5/20/2008 13:05	Chromium, Total, ICP-MS	0.81	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.4	2
NED09IN	5/20/2008 13:05	Copper, Total, ICP-MS	5.88	$\mu\text{g}\cdot\text{L}^{-1}$		0.4	2
NED09IN	5/20/2008 13:05	Dilution Factor	1	none			

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
NED09IN	5/20/2008 13:05	Dilution Factor	1	none			
NED09IN	5/20/2008 13:05	Fecal Coliform	2700	CFU•100ml ⁻¹			
NED09IN	5/20/2008 13:05	Hardness, Calc	38.1	CaCO3•L ⁻¹		0.2	1.25
NED09IN	5/20/2008 13:05	Lead, Total, ICP-MS	1.01	µg•L ⁻¹		0.2	1
NED09IN	5/20/2008 13:05	Magnesium, Total, ICP-MS	2610	µg•L ⁻¹		30	150
NED09IN	5/20/2008 13:05	Manganese, Total, ICP-MS	10.4	µg•L ⁻¹		0.2	1
NED09IN	5/20/2008 13:05	Nickel, Total, ICP-MS	1.3	µg•L ⁻¹	<RDL	0.3	1.5
NED09IN	5/20/2008 13:05	Orthophosphate Phosphorus	0.0379	mg•L ⁻¹		0.002	0.005
NED09IN	5/20/2008 13:05	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NED09IN	5/20/2008 13:05	Total Nitrogen	0.994	mg•L ⁻¹		0.05	0.1
NED09IN	5/20/2008 13:05	Total Phosphorus	0.0742	mg•L ⁻¹		0.005	0.01
NED09IN	5/20/2008 13:05	Total Suspended Solids	5.31	mg•L ⁻¹		0.5	1
NED09OUT	3/11/2008 11:15	Zinc, Total, ICP-MS	5.41	µg•L ⁻¹		0.5	2.5
NED09IN	5/20/2008 13:05	pH	6.67	pH	H		
NED09IN	6/3/2008 11:35	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL	0.5	2.5
NED09IN	6/3/2008 11:35	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
NED09IN	6/3/2008 11:35	Calcium, Total, ICP-MS	3810	µg•L ⁻¹		50	250
NED09IN	6/3/2008 11:35	Chromium, Total, ICP-MS	1.2	µg•L ⁻¹	<RDL	0.4	2
NED09IN	6/3/2008 11:35	Copper, Total, ICP-MS	7.12	µg•L ⁻¹		0.4	2
NED09IN	6/3/2008 11:35	Dilution Factor	1	none			
NED09IN	6/3/2008 11:35	Dilution Factor	1	none			
NED09IN	6/3/2008 11:35	Fecal Coliform	560	CFU•100ml ⁻¹			
NED09IN	6/3/2008 11:35	Hardness, Calc	12.9	CaCO3•L ⁻¹		0.2	1.25
NED09IN	6/3/2008 11:35	Lead, Total, ICP-MS	1.76	µg•L ⁻¹		0.2	1
NED09IN	6/3/2008 11:35	Magnesium, Total, ICP-MS	822	µg•L ⁻¹		30	150
NED09IN	6/3/2008 11:35	Manganese, Total, ICP-MS	13	µg•L ⁻¹		0.2	1
NED09IN	6/3/2008 11:35	Nickel, Total, ICP-MS	1	µg•L ⁻¹	<RDL	0.3	1.5
NED09IN	6/3/2008 11:35	Orthophosphate Phosphorus	0.0261	mg•L ⁻¹		0.002	0.005
NED09IN	6/3/2008 11:35	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NED09IN	6/3/2008 11:35	Total Nitrogen	0.609	mg•L ⁻¹		0.05	0.1

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
NED09IN	6/3/2008 11:35	Total Phosphorus	0.0505	mg•L ⁻¹		0.005	0.01
NED09IN	6/3/2008 11:35	Total Suspended Solids	6.67	mg•L ⁻¹		0.6	1.1
NED09IN	5/20/2008 13:05	Zinc, Total, ICP-MS	421	µg•L ⁻¹		0.5	2.5
NED09IN	6/3/2008 11:35	pH	6.84	pH	H		
NED09OUT	3/11/2008 11:15	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL	0.5	2.5
NED09OUT	3/11/2008 11:15	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
NED09OUT	3/11/2008 11:15	Calcium, Total, ICP-MS	9660	µg•L ⁻¹		50	250
NED09OUT	3/11/2008 11:15	Chromium, Total, ICP-MS	0.62	µg•L ⁻¹	<RDL	0.4	2
NED09OUT	3/11/2008 11:15	Copper, Total, ICP-MS	2.87	µg•L ⁻¹		0.4	2
NED09OUT	3/11/2008 11:15	Fecal Coliform	25	CFU•100ml ⁻¹			
NED09OUT	3/11/2008 11:15	Hardness, Calc	35.2	CaCO3•L ⁻¹		0.2	1.25
NED09OUT	3/11/2008 11:15	Lead, Total, ICP-MS	0.8	µg•L ⁻¹	<RDL	0.2	1
NED09OUT	3/11/2008 11:15	Magnesium, Total, ICP-MS	2680	µg•L ⁻¹		30	150
NED09OUT	3/11/2008 11:15	Manganese, Total, ICP-MS	24.4	µg•L ⁻¹		0.2	1
NED09OUT	3/11/2008 11:15	Nickel, Total, ICP-MS	0.84	µg•L ⁻¹	<RDL	0.3	1.5
NED09OUT	3/11/2008 11:15	Orthophosphate Phosphorus	0.0027	mg•L ⁻¹	<RDL	0.002	0.005
NED09OUT	3/11/2008 11:15	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NED09OUT	3/11/2008 11:15	Total Nitrogen	0.489	mg•L ⁻¹		0.05	0.1
NED09OUT	3/11/2008 11:15	Total Phosphorus	0.025	mg•L ⁻¹		0.005	0.01
NED09OUT	3/11/2008 11:15	Total Suspended Solids	4.95	mg•L ⁻¹		0.5	1.1
NED09OUT	5/20/2008 13:17	Zinc, Total, ICP-MS	86.3	µg•L ⁻¹		0.5	2.5
NED09OUT	3/11/2008 11:15	pH	7.4	pH	H		
NED09OUT	5/20/2008 13:17	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL	0.5	2.5
NED09OUT	5/20/2008 13:17	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
NED09OUT	5/20/2008 13:17	Calcium, Total, ICP-MS	10500	µg•L ⁻¹		50	250
NED09OUT	5/20/2008 13:17	Chromium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.4	2
NED09OUT	5/20/2008 13:17	Copper, Total, ICP-MS	2.55	µg•L ⁻¹		0.4	2
NED09OUT	5/20/2008 13:17	Fecal Coliform	120	CFU•100ml ⁻¹			
NED09OUT	5/20/2008 13:17	Hardness, Calc	38.9	CaCO3•L ⁻¹		0.2	1.25
NED09OUT	5/20/2008 13:17	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
NED09OUT	5/20/2008 13:17	Magnesium, Total, ICP-MS	3080	µg•L ⁻¹		30	150
NED09OUT	5/20/2008 13:17	Manganese, Total, ICP-MS	43.7	µg•L ⁻¹		0.2	1
NED09OUT	5/20/2008 13:17	Nickel, Total, ICP-MS	0.71	µg•L ⁻¹	<RDL	0.3	1.5
NED09OUT	5/20/2008 13:17	Orthophosphate Phosphorus	0.00911	mg•L ⁻¹		0.002	0.005
NED09OUT	5/20/2008 13:17	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NED09OUT	5/20/2008 13:17	Total Nitrogen	0.458	mg•L ⁻¹		0.05	0.1
NED09OUT	5/20/2008 13:17	Total Phosphorus	0.0257	mg•L ⁻¹		0.005	0.01
NED09OUT	5/20/2008 13:17	Total Suspended Solids	1	mg•L ⁻¹	<RDL	0.6	1.3
NED09IN	6/3/2008 11:35	Zinc, Total, ICP-MS	59.9	µg•L ⁻¹		0.5	2.5
NED09OUT	5/20/2008 13:17	pH	6.98	pH	H		
NED09OUT	6/3/2008 11:45	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL	0.5	2.5
NED09OUT	6/3/2008 11:45	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
NED09OUT	6/3/2008 11:45	Calcium, Total, ICP-MS	11900	µg•L ⁻¹		50	250
NED09OUT	6/3/2008 11:45	Chromium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.4	2
NED09OUT	6/3/2008 11:45	Copper, Total, ICP-MS	2.16	µg•L ⁻¹		0.4	2
NED09OUT	6/3/2008 11:45	Fecal Coliform	10	CFU•100ml ⁻¹			
NED09OUT	6/3/2008 11:45	Hardness, Calc	44.1	CaCO3•L ⁻¹		0.2	1.25
NED09OUT	6/3/2008 11:45	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NED09OUT	6/3/2008 11:45	Magnesium, Total, ICP-MS	3500	µg•L ⁻¹		30	150
NED09OUT	6/3/2008 11:45	Manganese, Total, ICP-MS	53.5	µg•L ⁻¹		0.2	1
NED09OUT	6/3/2008 11:45	Nickel, Total, ICP-MS	0.86	µg•L ⁻¹	<RDL	0.3	1.5
NED09OUT	6/3/2008 11:45	Orthophosphate Phosphorus	0.0031	mg•L ⁻¹	<RDL	0.002	0.005
NED09OUT	6/3/2008 11:45	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NED09OUT	6/3/2008 11:45	Total Nitrogen	0.623	mg•L ⁻¹		0.05	0.1
NED09OUT	6/3/2008 11:45	Total Phosphorus	0.0545	mg•L ⁻¹		0.005	0.01
NED09OUT	6/3/2008 11:45	Total Suspended Solids	4.05	mg•L ⁻¹		1.4	2.7
NED09OUT	6/3/2008 11:45	Zinc, Total, ICP-MS	313	µg•L ⁻¹		0.5	2.5
NED09OUT	6/3/2008 11:45	pH	7.07	pH	H		
NWD04IN	3/11/2008 10:40	Arsenic, Total, ICP-MS	0.51	µg•L ⁻¹	<RDL	0.5	2.5
NWD04IN	3/11/2008 10:40	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
NWD04IN	3/11/2008 10:40	Calcium, Total, ICP-MS	13700	$\mu\text{g}\cdot\text{L}^{-1}$		50	250
NWD04IN	3/11/2008 10:40	Chromium, Total, ICP-MS	0.82	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.4	2
NWD04IN	3/11/2008 10:40	Copper, Total, ICP-MS	5.69	$\mu\text{g}\cdot\text{L}^{-1}$		0.4	2
NWD04IN	3/11/2008 10:40	Fecal Coliform	3	$\text{CFU}\cdot 100\text{ml}^{-1}$			
NWD04IN	3/11/2008 10:40	Hardness, Calc	43.8	$\text{CaCO}_3\cdot\text{L}^{-1}$		0.2	1.25
NWD04IN	3/11/2008 10:40	Lead, Total, ICP-MS	0.32	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.2	1
NWD04IN	3/11/2008 10:40	Magnesium, Total, ICP-MS	2360	$\mu\text{g}\cdot\text{L}^{-1}$		30	150
NWD04IN	3/11/2008 10:40	Manganese, Total, ICP-MS	9.12	$\mu\text{g}\cdot\text{L}^{-1}$		0.2	1
NWD04IN	3/11/2008 10:40	Nickel, Total, ICP-MS	0.75	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.3	1.5
NWD04IN	3/11/2008 10:40	Orthophosphate Phosphorus	0.0135	$\text{mg}\cdot\text{L}^{-1}$		0.002	0.005
NWD04IN	3/11/2008 10:40	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
NWD04IN	3/11/2008 10:40	Total Nitrogen	0.948	$\text{mg}\cdot\text{L}^{-1}$		0.05	0.1
NWD04IN	3/11/2008 10:40	Total Phosphorus	0.0306	$\text{mg}\cdot\text{L}^{-1}$		0.005	0.01
NWD04IN	3/11/2008 10:40	Total Suspended Solids	2.3	$\text{mg}\cdot\text{L}^{-1}$		0.5	1
NWD04IN	3/11/2008 10:40	Zinc, Total, ICP-MS	5.68	$\mu\text{g}\cdot\text{L}^{-1}$		0.5	2.5
NWD04IN	3/11/2008 10:40	pH	7.78	pH	H		
NWD04IN	5/20/2008 12:24	Arsenic, Total, ICP-MS	0.73	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.5	2.5
NWD04IN	5/20/2008 12:24	Cadmium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.1	0.5
NWD04IN	5/20/2008 12:24	Calcium, Total, ICP-MS	13800	$\mu\text{g}\cdot\text{L}^{-1}$		50	250
NWD04IN	5/20/2008 12:24	Chromium, Total, ICP-MS	0.95	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.4	2
NWD04IN	5/20/2008 12:24	Copper, Total, ICP-MS	6.56	$\mu\text{g}\cdot\text{L}^{-1}$		0.4	2
NWD04IN	5/20/2008 12:24	Fecal Coliform	3200	$\text{CFU}\cdot 100\text{ml}^{-1}$			
NWD04IN	5/20/2008 12:24	Hardness, Calc	45.7	$\text{CaCO}_3\cdot\text{L}^{-1}$		0.2	1.25
NWD04IN	5/20/2008 12:24	Lead, Total, ICP-MS	0.42	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.2	1
NWD04IN	5/20/2008 12:24	Magnesium, Total, ICP-MS	2730	$\mu\text{g}\cdot\text{L}^{-1}$		30	150
NWD04IN	5/20/2008 12:24	Manganese, Total, ICP-MS	11.5	$\mu\text{g}\cdot\text{L}^{-1}$		0.2	1
NWD04IN	5/20/2008 12:24	Nickel, Total, ICP-MS	1.1	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.3	1.5
NWD04IN	5/20/2008 12:24	Orthophosphate Phosphorus	0.0433	$\text{mg}\cdot\text{L}^{-1}$		0.002	0.005
NWD04IN	5/20/2008 12:24	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
NWD04IN	5/20/2008 12:24	Total Nitrogen	1.56	$\text{mg}\cdot\text{L}^{-1}$		0.05	0.1

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
NWD04IN	5/20/2008 12:24	Total Phosphorus	0.0796	mg•L ⁻¹		0.005	0.01
NWD04IN	5/20/2008 12:24	Total Suspended Solids	4.04	mg•L ⁻¹		1	1.9
NWD04IN	5/20/2008 12:24	Zinc, Total, ICP-MS	4.81	µg•L ⁻¹		0.5	2.5
NWD04IN	5/20/2008 12:24	pH	7.03	pH	H		
NWD04IN	6/3/2008 11:00	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL	0.5	2.5
NWD04IN	6/3/2008 11:00	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
NWD04IN	6/3/2008 11:00	Calcium, Total, ICP-MS	8200	µg•L ⁻¹		50	250
NWD04IN	6/3/2008 11:00	Chromium, Total, ICP-MS	0.53	µg•L ⁻¹	<RDL	0.4	2
NWD04IN	6/3/2008 11:00	Copper, Total, ICP-MS	4.72	µg•L ⁻¹		0.4	2
NWD04IN	6/3/2008 11:00	Fecal Coliform	2900	CFU•100ml ⁻¹			
NWD04IN	6/3/2008 11:00	Hardness, Calc	25.8	CaCO3•L ⁻¹		0.2	1.25
NWD04IN	6/3/2008 11:00	Lead, Total, ICP-MS	0.39	µg•L ⁻¹	<RDL	0.2	1
NWD04IN	6/3/2008 11:00	Magnesium, Total, ICP-MS	1300	µg•L ⁻¹		30	150
NWD04IN	6/3/2008 11:00	Manganese, Total, ICP-MS	10.7	µg•L ⁻¹		0.2	1
NWD04IN	6/3/2008 11:00	Nickel, Total, ICP-MS	0.64	µg•L ⁻¹	<RDL	0.3	1.5
NWD04IN	6/3/2008 11:00	Orthophosphate Phosphorus	0.0311	mg•L ⁻¹		0.002	0.005
NWD04IN	6/3/2008 11:00	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NWD04IN	6/3/2008 11:00	Total Nitrogen	1.07	mg•L ⁻¹		0.05	0.1
NWD04IN	6/3/2008 11:00	Total Phosphorus	0.101	mg•L ⁻¹		0.005	0.01
NWD04IN	6/3/2008 11:00	Total Suspended Solids	2.75	mg•L ⁻¹		1	2
NWD04IN	6/3/2008 11:00	Zinc, Total, ICP-MS	3.9	µg•L ⁻¹		0.5	2.5
NWD04IN	6/3/2008 11:00	pH	7.19	pH	H		
NWD04OUT	3/11/2008 10:50	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL	0.5	2.5
NWD04OUT	3/11/2008 10:50	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
NWD04OUT	3/11/2008 10:50	Calcium, Total, ICP-MS	12900	µg•L ⁻¹		50	250
NWD04OUT	3/11/2008 10:50	Chromium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.4	2
NWD04OUT	3/11/2008 10:50	Copper, Total, ICP-MS	1.6	µg•L ⁻¹	<RDL	0.4	2
NWD04OUT	3/11/2008 10:50	Fecal Coliform	4	CFU•100ml ⁻¹			
NWD04OUT	3/11/2008 10:50	Hardness, Calc	44.7	CaCO3•L ⁻¹		0.2	1.25
NWD04OUT	3/11/2008 10:50	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
NWD04OUT	3/11/2008 10:50	Magnesium, Total, ICP-MS	3010	µg•L ⁻¹		30	150
NWD04OUT	3/11/2008 10:50	Manganese, Total, ICP-MS	31.3	µg•L ⁻¹		0.2	1
NWD04OUT	3/11/2008 10:50	Nickel, Total, ICP-MS	0.48	µg•L ⁻¹	<RDL	0.3	1.5
NWD04OUT	3/11/2008 10:50	Orthophosphate Phosphorus	0.0034	mg•L ⁻¹	<RDL	0.002	0.005
NWD04OUT	3/11/2008 10:50	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NWD04OUT	3/11/2008 10:50	Total Nitrogen	0.241	mg•L ⁻¹		0.05	0.1
NWD04OUT	3/11/2008 10:50	Total Phosphorus	0.0122	mg•L ⁻¹		0.005	0.01
NWD04OUT	3/11/2008 10:50	Total Suspended Solids	0.7	mg•L ⁻¹	<RDL	0.5	1
NWD04OUT	3/11/2008 10:50	Zinc, Total, ICP-MS	0.66	µg•L ⁻¹	<RDL	0.5	2.5
NWD04OUT	3/11/2008 10:50	pH	8.41	pH	H		
NWD04OUT	5/20/2008 12:50	Arsenic, Total, ICP-MS	1.1	µg•L ⁻¹	<RDL	0.5	2.5
NWD04OUT	5/20/2008 12:50	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
NWD04OUT	5/20/2008 12:50	Calcium, Total, ICP-MS	10300	µg•L ⁻¹		50	250
NWD04OUT	5/20/2008 12:50	Chromium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.4	2
NWD04OUT	5/20/2008 12:50	Copper, Total, ICP-MS	3.08	µg•L ⁻¹		0.4	2
NWD04OUT	5/20/2008 12:50	Fecal Coliform	16	CFU•100ml ⁻¹			
NWD04OUT	5/20/2008 12:50	Hardness, Calc	32.7	CaCO3•L ⁻¹		0.2	1.25
NWD04OUT	5/20/2008 12:50	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NWD04OUT	5/20/2008 12:50	Magnesium, Total, ICP-MS	1670	µg•L ⁻¹		30	150
NWD04OUT	5/20/2008 12:50	Manganese, Total, ICP-MS	28.3	µg•L ⁻¹		0.2	1
NWD04OUT	5/20/2008 12:50	Nickel, Total, ICP-MS	0.57	µg•L ⁻¹	<RDL	0.3	1.5
NWD04OUT	5/20/2008 12:50	Orthophosphate Phosphorus	0.00715	mg•L ⁻¹		0.002	0.005
NWD04OUT	5/20/2008 12:50	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
NWD04OUT	5/20/2008 12:50	Total Nitrogen	0.37	mg•L ⁻¹		0.05	0.1
NWD04OUT	5/20/2008 12:50	Total Phosphorus	0.0258	mg•L ⁻¹		0.005	0.01
NWD04OUT	5/20/2008 12:50	Total Suspended Solids	1.91	mg•L ⁻¹		0.6	1.1
NWD04OUT	5/20/2008 12:50	Zinc, Total, ICP-MS	1	µg•L ⁻¹	<RDL	0.5	2.5
NWD04OUT	5/20/2008 12:50	pH	10	pH	H		
NWD04OUT	6/3/2008 11:15	Arsenic, Total, ICP-MS	1.2	µg•L ⁻¹	<RDL	0.5	2.5
NWD04OUT	6/3/2008 11:15	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
NWD04OUT	6/3/2008 11:15	Calcium, Total, ICP-MS	11000	$\mu\text{g}\cdot\text{L}^{-1}$		50	250
NWD04OUT	6/3/2008 11:15	Chromium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.4	2
NWD04OUT	6/3/2008 11:15	Copper, Total, ICP-MS	2.84	$\mu\text{g}\cdot\text{L}^{-1}$		0.4	2
NWD04OUT	6/3/2008 11:15	Fecal Coliform	13	$\text{CFU}\cdot 100\text{ml}^{-1}$			
NWD04OUT	6/3/2008 11:15	Hardness, Calc	35	$\text{CaCO}_3\cdot\text{L}^{-1}$		0.2	1.25
NWD04OUT	6/3/2008 11:15	Lead, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
NWD04OUT	6/3/2008 11:15	Magnesium, Total, ICP-MS	1800	$\mu\text{g}\cdot\text{L}^{-1}$		30	150
NWD04OUT	6/3/2008 11:15	Manganese, Total, ICP-MS	43.2	$\mu\text{g}\cdot\text{L}^{-1}$		0.2	1
NWD04OUT	6/3/2008 11:15	Nickel, Total, ICP-MS	0.5	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.3	1.5
NWD04OUT	6/3/2008 11:15	Orthophosphate Phosphorus	0.0107	$\text{mg}\cdot\text{L}^{-1}$		0.002	0.005
NWD04OUT	6/3/2008 11:15	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
NWD04OUT	6/3/2008 11:15	Total Nitrogen	0.553	$\text{mg}\cdot\text{L}^{-1}$		0.05	0.1
NWD04OUT	6/3/2008 11:15	Total Phosphorus	0.0413	$\text{mg}\cdot\text{L}^{-1}$		0.005	0.01
NWD04OUT	6/3/2008 11:15	Total Suspended Solids	1.3	$\text{mg}\cdot\text{L}^{-1}$	<RDL	0.9	1.9
NWD04OUT	6/3/2008 11:15	Zinc, Total, ICP-MS	0.93	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.5	2.5
NWD04OUT	6/3/2008 11:15	pH	9.66	pH	H		
SWD03	3/11/2008 11:45	Arsenic, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.5	2.5
SWD03	3/11/2008 11:45	Cadmium, Total, ICP-MS	0.31	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.1	0.5
SWD03	3/11/2008 11:45	Calcium, Total, ICP-MS	14200	$\mu\text{g}\cdot\text{L}^{-1}$		50	250
SWD03	3/11/2008 11:45	Chromium, Total, ICP-MS	0.41	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.4	2
SWD03	3/11/2008 11:45	Copper, Total, ICP-MS	5.18	$\mu\text{g}\cdot\text{L}^{-1}$		0.4	2
SWD03	3/11/2008 11:45	Fecal Coliform	3	$\text{CFU}\cdot 100\text{ml}^{-1}$			
SWD03	3/11/2008 11:45	Hardness, Calc	51.6	$\text{CaCO}_3\cdot\text{L}^{-1}$		0.2	1.25
SWD03	3/11/2008 11:45	Lead, Total, ICP-MS	0.24	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.2	1
SWD03	3/11/2008 11:45	Magnesium, Total, ICP-MS	3920	$\mu\text{g}\cdot\text{L}^{-1}$		30	150
SWD03	3/11/2008 11:45	Manganese, Total, ICP-MS	104	$\mu\text{g}\cdot\text{L}^{-1}$		0.2	1
SWD03	3/11/2008 11:45	Nickel, Total, ICP-MS	3.71	$\mu\text{g}\cdot\text{L}^{-1}$		0.3	1.5
SWD03	3/11/2008 11:45	Orthophosphate Phosphorus	0.0101	$\text{mg}\cdot\text{L}^{-1}$		0.002	0.005
SWD03	3/11/2008 11:45	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
SWD03	3/11/2008 11:45	Total Nitrogen	0.712	$\text{mg}\cdot\text{L}^{-1}$		0.05	0.1

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
SWD03	3/11/2008 11:45	Total Phosphorus	0.0432	mg•L ⁻¹		0.005	0.01
SWD03	3/11/2008 11:45	Total Suspended Solids	3.03	mg•L ⁻¹		0.6	1.1
SWD03	3/11/2008 11:45	Zinc, Total, ICP-MS	4.34	µg•L ⁻¹		0.5	2.5
SWD03	3/11/2008 11:45	pH	7.46	pH	H		
SWD03	5/20/2008 12:05	Arsenic, Total, ICP-MS	0.57	µg•L ⁻¹	<RDL	0.5	2.5
SWD03	5/20/2008 12:05	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
SWD03	5/20/2008 12:05	Calcium, Total, ICP-MS	12900	µg•L ⁻¹		50	250
SWD03	5/20/2008 12:05	Chromium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.4	2
SWD03	5/20/2008 12:05	Copper, Total, ICP-MS	3.77	µg•L ⁻¹		0.4	2
SWD03	5/20/2008 12:05	Fecal Coliform	580	CFU•100ml ⁻¹			
SWD03	5/20/2008 12:05	Hardness, Calc	47.8	CaCO3•L ⁻¹		0.2	1.25
SWD03	5/20/2008 12:05	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
SWD03	5/20/2008 12:05	Magnesium, Total, ICP-MS	3800	µg•L ⁻¹		30	150
SWD03	5/20/2008 12:05	Manganese, Total, ICP-MS	178	µg•L ⁻¹		0.2	1
SWD03	5/20/2008 12:05	Nickel, Total, ICP-MS	3.38	µg•L ⁻¹		0.3	1.5
SWD03	5/20/2008 12:05	Orthophosphate Phosphorus	0.0266	mg•L ⁻¹		0.002	0.005
SWD03	5/20/2008 12:05	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
SWD03	5/20/2008 12:05	Total Nitrogen	1.28	mg•L ⁻¹		0.05	0.1
SWD03	5/20/2008 12:05	Total Phosphorus	0.101	mg•L ⁻¹		0.005	0.01
SWD03	5/20/2008 12:05	Total Suspended Solids	4.17	mg•L ⁻¹		0.5	1
SWD03	5/20/2008 12:05	Zinc, Total, ICP-MS	3.7	µg•L ⁻¹		0.5	2.5
SWD03	5/20/2008 12:05	pH	7.36	pH	H		
SWD03	6/3/2008 12:00	Arsenic, Total, ICP-MS	0.61	µg•L ⁻¹	<RDL	0.5	2.5
SWD03	6/3/2008 12:00	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
SWD03	6/3/2008 12:00	Calcium, Total, ICP-MS	13700	µg•L ⁻¹		50	250
SWD03	6/3/2008 12:00	Chromium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.4	2
SWD03	6/3/2008 12:00	Copper, Total, ICP-MS	2.31	µg•L ⁻¹		0.4	2
SWD03	6/3/2008 12:00	Fecal Coliform	2500	CFU•100ml ⁻¹			
SWD03	6/3/2008 12:00	Hardness, Calc	51.5	CaCO3•L ⁻¹		0.2	1.25
SWD03	6/3/2008 12:00	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
SWD03	6/3/2008 12:00	Magnesium, Total, ICP-MS	4210	$\mu\text{g}\cdot\text{L}^{-1}$		30	150
SWD03	6/3/2008 12:00	Manganese, Total, ICP-MS	520	$\mu\text{g}\cdot\text{L}^{-1}$		0.2	1
SWD03	6/3/2008 12:00	Nickel, Total, ICP-MS	3.08	$\mu\text{g}\cdot\text{L}^{-1}$		0.3	1.5
SWD03	6/3/2008 12:00	Orthophosphate Phosphorus	0.0381	$\text{mg}\cdot\text{L}^{-1}$		0.002	0.005
SWD03	6/3/2008 12:00	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
SWD03	6/3/2008 12:00	Total Nitrogen	1.07	$\text{mg}\cdot\text{L}^{-1}$		0.05	0.1
SWD03	6/3/2008 12:00	Total Phosphorus	0.141	$\text{mg}\cdot\text{L}^{-1}$		0.005	0.01
SWD03	6/3/2008 12:00	Total Suspended Solids	4.4	$\text{mg}\cdot\text{L}^{-1}$		2	4
SWD03	6/3/2008 12:00	Zinc, Total, ICP-MS	2	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.5	2.5
SWD03	6/3/2008 12:00	pH	7.75	pH	H		
ECW01BIN	3/7/2008 23:35	Arsenic, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL,H	0.5	2.5
ECW01BIN	3/7/2008 23:35	Cadmium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL,H	0.1	0.5
ECW01BIN	3/7/2008 23:35	Calcium, Total, ICP-MS	14400	$\mu\text{g}\cdot\text{L}^{-1}$	H	50	250
ECW01BIN	3/7/2008 23:35	Chromium, Total, ICP-MS	0.92	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL,H	0.4	2
ECW01BIN	3/7/2008 23:35	Copper, Total, ICP-MS	4.48	$\mu\text{g}\cdot\text{L}^{-1}$	H	0.4	2
ECW01BIN	3/7/2008 23:35	Hardness, Calc	47.7	$\text{CaCO}_3\cdot\text{L}^{-1}$	H	0.2	1.25
ECW01BIN	3/7/2008 23:35	Lead, Total, ICP-MS	1.49	$\mu\text{g}\cdot\text{L}^{-1}$	H	0.2	1
ECW01BIN	3/7/2008 23:35	Magnesium, Total, ICP-MS	2860	$\mu\text{g}\cdot\text{L}^{-1}$	H	30	150
ECW01BIN	3/7/2008 23:35	Manganese, Total, ICP-MS	72.1	$\mu\text{g}\cdot\text{L}^{-1}$	H	0.2	1
ECW01BIN	3/7/2008 23:35	Nickel, Total, ICP-MS	1.2	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL,H	0.3	1.5
ECW01BIN	3/7/2008 23:35	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL,H	0.2	1
ECW01BIN	3/7/2008 23:35	Total Nitrogen	2.49	$\text{mg}\cdot\text{L}^{-1}$	H	0.05	0.1
ECW01BIN	3/7/2008 23:35	Total Phosphorus	0.212	$\text{mg}\cdot\text{L}^{-1}$	H	0.005	0.01
ECW01BIN	3/7/2008 23:35	Total Suspended Solids	15.2	$\text{mg}\cdot\text{L}^{-1}$		1.1	2.2
ECW01BIN	3/7/2008 23:35	Zinc, Total, ICP-MS	14.1	$\mu\text{g}\cdot\text{L}^{-1}$	H	0.5	2.5
ECW01BIN	3/7/2008 23:35	pH	7.63	pH	H		
ECW01BIN	3/7/2008 23:35	pH, Field	7.4	pH			
ECW01BIN	5/19/2008 13:45	Fecal Coliform	3	$\text{CFU}\cdot 100\text{ml}^{-1}$			
ECW01BIN	5/13/2008 13:00	Arsenic, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.5	2.5
ECW01BIN	5/13/2008 13:00	Cadmium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.1	0.5

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW01BIN	5/13/2008 13:00	Calcium, Total, ICP-MS	13000	µg•L ⁻¹		50	250
ECW01BIN	5/13/2008 13:00	Chromium, Total, ICP-MS	0.47	µg•L ⁻¹	<RDL	0.4	2
ECW01BIN	5/13/2008 13:00	Copper, Total, ICP-MS	3.74	µg•L ⁻¹		0.4	2
ECW01BIN	5/13/2008 13:00	Hardness, Calc	43.6	CaCO3•L ⁻¹		0.2	1.25
ECW01BIN	5/13/2008 13:00	Lead, Total, ICP-MS	0.35	µg•L ⁻¹	<RDL	0.2	1
ECW01BIN	5/13/2008 13:00	Magnesium, Total, ICP-MS	2700	µg•L ⁻¹		30	150
ECW01BIN	5/13/2008 13:00	Manganese, Total, ICP-MS	14.2	µg•L ⁻¹		0.2	1
ECW01BIN	5/13/2008 13:00	Nickel, Total, ICP-MS	0.83	µg•L ⁻¹	<RDL	0.3	1.5
ECW01BIN	5/13/2008 13:00	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
ECW01BIN	5/13/2008 13:00	Total Nitrogen	0.81	mg•L ⁻¹	H	0.05	0.1
ECW01BIN	5/13/2008 13:00	Total Phosphorus	0.0347	mg•L ⁻¹	H	0.005	0.01
ECW01BIN	5/13/2008 13:00	Total Suspended Solids	4.12	mg•L ⁻¹		1	2
ECW01BIN	5/13/2008 13:00	Zinc, Total, ICP-MS	17	µg•L ⁻¹		0.5	2.5
ECW01BIN	5/13/2008 13:00	pH	7.05	pH	H		
ECW01BIN	10/2/2008 16:00	Arsenic, Total, ICP-MS	0.38	µg•L ⁻¹	<RDL	0.1	0.5
ECW01BIN	10/2/2008 16:00	Cadmium, Total, ICP-MS	0.096	µg•L ⁻¹	<RDL	0.05	0.25
ECW01BIN	10/2/2008 16:00	Calcium, Total, ICP-MS	10300	µg•L ⁻¹		10	50
ECW01BIN	10/2/2008 16:00	Chromium, Total, ICP-MS	0.9	µg•L ⁻¹	<RDL	0.2	1
ECW01BIN	10/2/2008 16:00	Copper, Total, ICP-MS	4.77	µg•L ⁻¹		0.4	2
ECW01BIN	10/2/2008 16:00	Hardness, Calc	33.1	CaCO3•L ⁻¹		0.2	1.25
ECW01BIN	10/2/2008 16:00	Lead, Total, ICP-MS	1.88	µg•L ⁻¹		0.1	0.1
ECW01BIN	10/2/2008 16:00	Magnesium, Total, ICP-MS	1810	µg•L ⁻¹		10	50
ECW01BIN	10/2/2008 16:00	Manganese, Total, ICP-MS	23.4	µg•L ⁻¹		0.05	0.25
ECW01BIN	10/2/2008 16:00	Nickel, Total, ICP-MS	0.973	µg•L ⁻¹		0.1	0.5
ECW01BIN	10/2/2008 16:00	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW01BIN	10/2/2008 16:00	Total Nitrogen	0.757	mg•L ⁻¹	H	0.05	0.1
ECW01BIN	10/2/2008 16:00	Total Phosphorus	0.0467	mg•L ⁻¹	H	0.005	0.01
ECW01BIN	10/2/2008 16:00	Total Suspended Solids	9.18	mg•L ⁻¹		0.5	1
ECW01BIN	10/2/2008 16:00	Zinc, Total, ICP-MS	181	µg•L ⁻¹		0.5	2.5
ECW01BIN	10/2/2008 16:00	pH	6.76	pH	H		

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW01BIN	10/2/2008 16:00	pH, Field	7.6	pH			
ECW01BIN	10/8/2008 14:30	Fecal Coliform	11	CFU•100ml ⁻¹			
ECW01BIN	11/10/2008 14:00	Fecal Coliform	4	CFU•100ml ⁻¹			
ECW01BIN	11/6/2008 2:40	Arsenic, Total, ICP-MS	0.4	µg•L ⁻¹	<RDL	0.1	0.5
ECW01BIN	11/6/2008 2:40	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW01BIN	11/6/2008 2:40	Calcium, Total, ICP-MS	14500	µg•L ⁻¹		10	50
ECW01BIN	11/6/2008 2:40	Chromium, Total, ICP-MS	0.5	µg•L ⁻¹	<RDL	0.2	1
ECW01BIN	11/6/2008 2:40	Copper, Total, ICP-MS	5.87	µg•L ⁻¹		0.4	2
ECW01BIN	11/6/2008 2:40	Hardness, Calc	50.3	CaCO3•L ⁻¹		0.066	0.331
ECW01BIN	11/6/2008 2:40	Iron, Total, ICP-MS	174	µg•L ⁻¹		10	10
ECW01BIN	11/6/2008 2:40	Lead, Total, ICP-MS	0.567	µg•L ⁻¹		0.075	0.1
ECW01BIN	11/6/2008 2:40	Magnesium, Total, ICP-MS	3450	µg•L ⁻¹		10	50
ECW01BIN	11/6/2008 2:40	Manganese, Total, ICP-MS	13.3	µg•L ⁻¹		0.1	0.5
ECW01BIN	11/6/2008 2:40	Nickel, Total, ICP-MS	0.961	µg•L ⁻¹		0.1	0.5
ECW01BIN	11/6/2008 2:40	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW01BIN	11/6/2008 2:40	Total Nitrogen	1.4	mg•L ⁻¹	H	0.05	0.1
ECW01BIN	11/6/2008 2:40	Total Phosphorus	0.0359	mg•L ⁻¹	H	0.005	0.01
ECW01BIN	11/6/2008 2:40	Total Suspended Solids	2.6	mg•L ⁻¹		0.5	1
ECW01BIN	11/6/2008 2:40	Zinc, Total, ICP-MS	4.94	µg•L ⁻¹		0.5	2.5
ECW01BIN	11/6/2008 2:40	pH	7.19	pH	H		
ECW01BIN	11/6/2008 2:40	pH, Field	6.6	pH			
ECW01BIN	12/7/2008 5:39	Arsenic, Total, ICP-MS	0.45	µg•L ⁻¹	<RDL	0.1	0.5
ECW01BIN	12/7/2008 5:39	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW01BIN	12/7/2008 5:39	Calcium, Total, ICP-MS	15100	µg•L ⁻¹		10	50
ECW01BIN	12/7/2008 5:39	Chromium, Total, ICP-MS	1.17	µg•L ⁻¹		0.2	1
ECW01BIN	12/7/2008 5:39	Copper, Total, ICP-MS	5.74	µg•L ⁻¹		0.4	2
ECW01BIN	12/7/2008 5:39	Hardness, Calc	53.1	CaCO3•L ⁻¹		0.066	0.331
ECW01BIN	12/7/2008 5:39	Lead, Total, ICP-MS	1.81	µg•L ⁻¹		0.075	0.1
ECW01BIN	12/7/2008 5:39	Magnesium, Total, ICP-MS	3710	µg•L ⁻¹		10	50
ECW01BIN	12/7/2008 5:39	Manganese, Total, ICP-MS	52.4	µg•L ⁻¹		0.1	0.5

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW01BIN	12/7/2008 5:39	Nickel, Total, ICP-MS	1.5	µg•L ⁻¹		0.1	0.5
ECW01BIN	12/7/2008 5:39	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW01BIN	12/7/2008 5:39	Total Nitrogen	0.927	mg•L ⁻¹	H	0.05	0.1
ECW01BIN	12/7/2008 5:39	Total Phosphorus	0.0487	mg•L ⁻¹	H	0.005	0.01
ECW01BIN	12/7/2008 5:39	Total Suspended Solids	21.5	mg•L ⁻¹		0.5	1
ECW01BIN	12/7/2008 5:39	Zinc, Total, ICP-MS	26.2	µg•L ⁻¹		0.5	2.5
ECW01BIN	12/7/2008 5:39	pH	7.06	pH	H		
ECW01BIN	12/7/2008 5:39	pH, Field	7.3	pH			
ECW01BIN	12/11/2008 14:03	Fecal Coliform	2	CFU•100ml ⁻¹			
ECW01BOUT	3/13/2008 13:30	Fecal Coliform	4	CFU•100ml ⁻¹			
ECW01BOUT	3/7/2008 20:55	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.5	2.5
ECW01BOUT	3/7/2008 20:55	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.1	0.5
ECW01BOUT	3/7/2008 20:55	Calcium, Total, ICP-MS	14300	µg•L ⁻¹	H	50	250
ECW01BOUT	3/7/2008 20:55	Chromium, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.4	2
ECW01BOUT	3/7/2008 20:55	Copper, Total, ICP-MS	3.41	µg•L ⁻¹	H	0.4	2
ECW01BOUT	3/7/2008 20:55	Hardness, Calc	50	CaCO3•L ⁻¹	H	0.2	1.25
ECW01BOUT	3/7/2008 20:55	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.2	1
ECW01BOUT	3/7/2008 20:55	Magnesium, Total, ICP-MS	3500	µg•L ⁻¹	H	30	150
ECW01BOUT	3/7/2008 20:55	Manganese, Total, ICP-MS	14.5	µg•L ⁻¹	H	0.2	1
ECW01BOUT	3/7/2008 20:55	Nickel, Total, ICP-MS	0.61	µg•L ⁻¹	<RDL,H	0.3	1.5
ECW01BOUT	3/7/2008 20:55	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.2	1
ECW01BOUT	3/7/2008 20:55	Total Nitrogen	0.494	mg•L ⁻¹	H	0.05	0.1
ECW01BOUT	3/7/2008 20:55	Total Phosphorus	0.0253	mg•L ⁻¹	H	0.005	0.01
ECW01BOUT	3/7/2008 20:55	Total Suspended Solids	1.6	mg•L ⁻¹	<RDL	1	2
ECW01BOUT	3/7/2008 20:55	Zinc, Total, ICP-MS	4.61	µg•L ⁻¹	H	0.5	2.5
ECW01BOUT	3/7/2008 20:55	pH	8.23	pH	H		
ECW01BOUT	3/7/2008 20:55	pH, Field	8.9	pH			
ECW01BOUT	5/19/2008 13:15	Fecal Coliform	0	CFU•100ml ⁻¹			
ECW01BOUT	5/13/2008 13:00	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL	0.5	2.5
ECW01BOUT	5/13/2008 13:00	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW01BOUT	5/13/2008 13:00	Calcium, Total, ICP-MS	16300	$\mu\text{g}\cdot\text{L}^{-1}$		50	250
ECW01BOUT	5/13/2008 13:00	Chromium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.4	2
ECW01BOUT	5/13/2008 13:00	Copper, Total, ICP-MS	3	$\mu\text{g}\cdot\text{L}^{-1}$		0.4	2
ECW01BOUT	5/13/2008 13:00	Hardness, Calc	59.2	$\text{CaCO}_3\cdot\text{L}^{-1}$		0.2	1.25
ECW01BOUT	5/13/2008 13:00	Lead, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
ECW01BOUT	5/13/2008 13:00	Magnesium, Total, ICP-MS	4460	$\mu\text{g}\cdot\text{L}^{-1}$		30	150
ECW01BOUT	5/13/2008 13:00	Manganese, Total, ICP-MS	46.3	$\mu\text{g}\cdot\text{L}^{-1}$		0.2	1
ECW01BOUT	5/13/2008 13:00	Nickel, Total, ICP-MS	0.79	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.3	1.5
ECW01BOUT	5/13/2008 13:00	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
ECW01BOUT	5/13/2008 13:00	Total Nitrogen	0.534	$\text{mg}\cdot\text{L}^{-1}$	H	0.05	0.1
ECW01BOUT	5/13/2008 13:00	Total Phosphorus	0.0184	$\text{mg}\cdot\text{L}^{-1}$	H	0.005	0.01
ECW01BOUT	5/13/2008 13:00	Total Suspended Solids	1.02	$\text{mg}\cdot\text{L}^{-1}$		0.5	1
ECW01BOUT	5/13/2008 13:00	Zinc, Total, ICP-MS	23.3	$\mu\text{g}\cdot\text{L}^{-1}$		0.5	2.5
ECW01BOUT	5/13/2008 13:00	pH	8.18	pH	H		
ECW01BOUT	10/2/2008 16:00	Arsenic, Total, ICP-MS	0.38	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.1	0.5
ECW01BOUT	10/2/2008 16:00	Cadmium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.05	0.25
ECW01BOUT	10/2/2008 16:00	Calcium, Total, ICP-MS	9040	$\mu\text{g}\cdot\text{L}^{-1}$		10	50
ECW01BOUT	10/2/2008 16:00	Chromium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.2	1
ECW01BOUT	10/2/2008 16:00	Copper, Total, ICP-MS	2.71	$\mu\text{g}\cdot\text{L}^{-1}$		0.4	2
ECW01BOUT	10/2/2008 16:00	Hardness, Calc	35.4	$\text{CaCO}_3\cdot\text{L}^{-1}$		0.2	1.25
ECW01BOUT	10/2/2008 16:00	Lead, Total, ICP-MS	0.179	$\mu\text{g}\cdot\text{L}^{-1}$		0.1	0.1
ECW01BOUT	10/2/2008 16:00	Magnesium, Total, ICP-MS	3110	$\mu\text{g}\cdot\text{L}^{-1}$		10	50
ECW01BOUT	10/2/2008 16:00	Manganese, Total, ICP-MS	7.63	$\mu\text{g}\cdot\text{L}^{-1}$		0.05	0.25
ECW01BOUT	10/2/2008 16:00	Nickel, Total, ICP-MS	0.645	$\mu\text{g}\cdot\text{L}^{-1}$		0.1	0.5
ECW01BOUT	10/2/2008 16:00	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.05	0.25
ECW01BOUT	10/2/2008 16:00	Total Nitrogen	0.4	$\text{mg}\cdot\text{L}^{-1}$	H	0.05	0.1
ECW01BOUT	10/2/2008 16:00	Total Phosphorus	0.0192	$\text{mg}\cdot\text{L}^{-1}$	H	0.005	0.01
ECW01BOUT	10/2/2008 16:00	Total Suspended Solids	2.16	$\text{mg}\cdot\text{L}^{-1}$		1	2
ECW01BOUT	10/2/2008 16:00	Zinc, Total, ICP-MS	3.24	$\mu\text{g}\cdot\text{L}^{-1}$		0.5	2.5
ECW01BOUT	10/2/2008 16:00	pH	7.15	pH	H		

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW01BOUT	10/2/2008 16:00	pH, Field	7.4	pH			
ECW01BOUT	10/8/2008 14:00	Fecal Coliform	3	CFU•100ml ⁻¹			
ECW01BOUT	11/10/2008 13:30	Fecal Coliform	19	CFU•100ml ⁻¹			
ECW01BOUT	11/6/2008 8:00	Arsenic, Total, ICP-MS	0.35	µg•L ⁻¹	<RDL	0.1	0.5
ECW01BOUT	11/6/2008 8:00	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW01BOUT	11/6/2008 8:00	Calcium, Total, ICP-MS	12100	µg•L ⁻¹		10	50
ECW01BOUT	11/6/2008 8:00	Chromium, Total, ICP-MS	0.45	µg•L ⁻¹	<RDL	0.2	1
ECW01BOUT	11/6/2008 8:00	Copper, Total, ICP-MS	5.22	µg•L ⁻¹		0.4	2
ECW01BOUT	11/6/2008 8:00	Hardness, Calc	42.4	CaCO3•L ⁻¹		0.066	0.331
ECW01BOUT	11/6/2008 8:00	Iron, Total, ICP-MS	169	µg•L ⁻¹		10	10
ECW01BOUT	11/6/2008 8:00	Lead, Total, ICP-MS	0.47	µg•L ⁻¹		0.075	0.1
ECW01BOUT	11/6/2008 8:00	Magnesium, Total, ICP-MS	2970	µg•L ⁻¹		10	50
ECW01BOUT	11/6/2008 8:00	Manganese, Total, ICP-MS	12.4	µg•L ⁻¹		0.1	0.5
ECW01BOUT	11/6/2008 8:00	Nickel, Total, ICP-MS	0.866	µg•L ⁻¹		0.1	0.5
ECW01BOUT	11/6/2008 8:00	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW01BOUT	11/6/2008 8:00	Total Nitrogen	0.962	mg•L ⁻¹	H	0.05	0.1
ECW01BOUT	11/6/2008 8:00	Total Phosphorus	0.027	mg•L ⁻¹	H	0.005	0.01
ECW01BOUT	11/6/2008 8:00	Total Suspended Solids	3.6	mg•L ⁻¹		0.5	1
ECW01BOUT	11/6/2008 8:00	Zinc, Total, ICP-MS	5.68	µg•L ⁻¹		0.5	2.5
ECW01BOUT	11/6/2008 8:00	pH	7.1	pH	H		
ECW01BOUT	11/6/2008 8:00	pH, Field	6.1	pH			
ECW01BOUT	12/7/2008 9:20	Arsenic, Total, ICP-MS	0.34	µg•L ⁻¹	<RDL	0.1	0.5
ECW01BOUT	12/7/2008 9:20	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW01BOUT	12/7/2008 9:20	Calcium, Total, ICP-MS	17700	µg•L ⁻¹		10	50
ECW01BOUT	12/7/2008 9:20	Chromium, Total, ICP-MS	0.31	µg•L ⁻¹	<RDL	0.2	1
ECW01BOUT	12/7/2008 9:20	Copper, Total, ICP-MS	2.87	µg•L ⁻¹		0.4	2
ECW01BOUT	12/7/2008 9:20	Hardness, Calc	62	CaCO3•L ⁻¹		0.066	0.331
ECW01BOUT	12/7/2008 9:20	Lead, Total, ICP-MS	0.181	µg•L ⁻¹		0.075	0.1
ECW01BOUT	12/7/2008 9:20	Magnesium, Total, ICP-MS	4330	µg•L ⁻¹		10	50
ECW01BOUT	12/7/2008 9:20	Manganese, Total, ICP-MS	19	µg•L ⁻¹		0.1	0.5

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW01BOUT	12/7/2008 9:20	Nickel, Total, ICP-MS	0.808	$\mu\text{g}\cdot\text{L}^{-1}$		0.1	0.5
ECW01BOUT	12/7/2008 9:20	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.05	0.25
ECW01BOUT	12/7/2008 9:20	Total Nitrogen	0.845	$\text{mg}\cdot\text{L}^{-1}$	H	0.05	0.1
ECW01BOUT	12/7/2008 9:20	Total Phosphorus	0.0345	$\text{mg}\cdot\text{L}^{-1}$	H	0.005	0.01
ECW01BOUT	12/7/2008 9:20	Total Suspended Solids	3.5	$\text{mg}\cdot\text{L}^{-1}$		0.5	1
ECW01BOUT	12/7/2008 9:20	Zinc, Total, ICP-MS	7.71	$\mu\text{g}\cdot\text{L}^{-1}$		0.5	2.5
ECW01BOUT	12/7/2008 9:20	pH	7.35	pH	H		
ECW01BOUT	12/7/2008 9:20	pH, Field	7.5	pH			
ECW01BOUT	12/11/2008 13:37	Fecal Coliform	1	$\text{CFU}\cdot 100\text{ml}^{-1}$			
ECW03IN	3/13/2008 12:55	Fecal Coliform	14	$\text{CFU}\cdot 100\text{ml}^{-1}$			
ECW03IN	3/7/2008 22:30	Arsenic, Total, ICP-MS	0.69	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL,H	0.5	2.5
ECW03IN	3/7/2008 22:30	Cadmium, Total, ICP-MS	0.28	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL,H	0.1	0.5
ECW03IN	3/7/2008 22:30	Calcium, Total, ICP-MS	21400	$\mu\text{g}\cdot\text{L}^{-1}$	H	50	250
ECW03IN	3/7/2008 22:30	Chromium, Total, ICP-MS	0.91	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL,H	0.4	2
ECW03IN	3/7/2008 22:30	Copper, Total, ICP-MS	6.19	$\mu\text{g}\cdot\text{L}^{-1}$	H	0.4	2
ECW03IN	3/7/2008 22:30	Hardness, Calc	71.4	$\text{CaCO}_3\cdot\text{L}^{-1}$	H	0.2	1.25
ECW03IN	3/7/2008 22:30	Lead, Total, ICP-MS	0.64	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL,H	0.2	1
ECW03IN	3/7/2008 22:30	Magnesium, Total, ICP-MS	4370	$\mu\text{g}\cdot\text{L}^{-1}$	H	30	150
ECW03IN	3/7/2008 22:30	Manganese, Total, ICP-MS	243	$\mu\text{g}\cdot\text{L}^{-1}$	H	0.2	1
ECW03IN	3/7/2008 22:30	Nickel, Total, ICP-MS	1.95	$\mu\text{g}\cdot\text{L}^{-1}$	H	0.3	1.5
ECW03IN	3/7/2008 22:30	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL,H	0.2	1
ECW03IN	3/7/2008 22:30	Total Nitrogen	6.32	$\text{mg}\cdot\text{L}^{-1}$	H	0.1	0.2
ECW03IN	3/7/2008 22:30	Total Phosphorus	0.691	$\text{mg}\cdot\text{L}^{-1}$	H	0.01	0.02
ECW03IN	3/7/2008 22:30	Total Suspended Solids	32.4	$\text{mg}\cdot\text{L}^{-1}$		2.9	5.9
ECW03IN	3/7/2008 22:30	Zinc, Total, ICP-MS	18.1	$\mu\text{g}\cdot\text{L}^{-1}$	H	0.5	2.5
ECW03IN	3/7/2008 22:30	pH	7.47	pH	H		
ECW03IN	3/7/2008 22:30	pH, Field	6.9	pH			
ECW03IN	5/19/2008 12:10	Fecal Coliform	4	$\text{CFU}\cdot 100\text{ml}^{-1}$			
ECW03IN	5/13/2008 13:00	Arsenic, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.5	2.5
ECW03IN	5/13/2008 13:00	Cadmium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.1	0.5

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW03IN	5/13/2008 13:00	Calcium, Total, ICP-MS	23800	µg•L ⁻¹		50	250
ECW03IN	5/13/2008 13:00	Chromium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.4	2
ECW03IN	5/13/2008 13:00	Copper, Total, ICP-MS	2.36	µg•L ⁻¹		0.4	2
ECW03IN	5/13/2008 13:00	Hardness, Calc	80.4	CaCO3•L ⁻¹		0.2	1.25
ECW03IN	5/13/2008 13:00	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
ECW03IN	5/13/2008 13:00	Magnesium, Total, ICP-MS	5130	µg•L ⁻¹		30	150
ECW03IN	5/13/2008 13:00	Manganese, Total, ICP-MS	32.6	µg•L ⁻¹		0.2	1
ECW03IN	5/13/2008 13:00	Nickel, Total, ICP-MS	0.76	µg•L ⁻¹	<RDL	0.3	1.5
ECW03IN	5/13/2008 13:00	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
ECW03IN	5/13/2008 13:00	Total Nitrogen	0.869	mg•L ⁻¹	H	0.05	0.1
ECW03IN	5/13/2008 13:00	Total Phosphorus	0.0353	mg•L ⁻¹	H	0.005	0.01
ECW03IN	5/13/2008 13:00	Total Suspended Solids	2.3	mg•L ⁻¹		0.5	1
ECW03IN	5/13/2008 13:00	Zinc, Total, ICP-MS	2.85	µg•L ⁻¹		0.5	2.5
ECW03IN	5/13/2008 13:00	pH	7.96	pH	H		
ECW03IN	10/2/2008 17:00	Arsenic, Total, ICP-MS	0.898	µg•L ⁻¹		0.1	0.5
ECW03IN	10/2/2008 17:00	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW03IN	10/2/2008 17:00	Calcium, Total, ICP-MS	12900	µg•L ⁻¹		10	50
ECW03IN	10/2/2008 17:00	Chromium, Total, ICP-MS	1.27	µg•L ⁻¹		0.2	1
ECW03IN	10/2/2008 17:00	Copper, Total, ICP-MS	6.23	µg•L ⁻¹		0.4	2
ECW03IN	10/2/2008 17:00	Hardness, Calc	42.1	CaCO3•L ⁻¹		0.2	1.25
ECW03IN	10/2/2008 17:00	Lead, Total, ICP-MS	1.1	µg•L ⁻¹		0.1	0.1
ECW03IN	10/2/2008 17:00	Magnesium, Total, ICP-MS	2370	µg•L ⁻¹		10	50
ECW03IN	10/2/2008 17:00	Manganese, Total, ICP-MS	94.4	µg•L ⁻¹		0.05	0.25
ECW03IN	10/2/2008 17:00	Nickel, Total, ICP-MS	3.08	µg•L ⁻¹		0.1	0.5
ECW03IN	10/2/2008 17:00	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW03IN	10/2/2008 17:00	Total Nitrogen	1.06	mg•L ⁻¹	H	0.05	0.1
ECW03IN	10/2/2008 17:00	Total Phosphorus	0.108	mg•L ⁻¹	H	0.005	0.01
ECW03IN	10/2/2008 17:00	Total Suspended Solids	18.1	mg•L ⁻¹		0.7	1.4
ECW03IN	10/2/2008 17:00	Zinc, Total, ICP-MS	15.4	µg•L ⁻¹		0.5	2.5
ECW03IN	10/2/2008 17:00	pH	7.19	pH	H		

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW03IN	10/2/2008 17:00	pH, Field	7.4	pH			
ECW03IN	10/8/2008 15:00	Fecal Coliform	120	CFU•100ml ⁻¹	C		
ECW03IN	11/10/2008 13:15	Fecal Coliform	42	CFU•100ml ⁻¹			
ECW03IN	11/6/2008 1:45	Arsenic, Total, ICP-MS	0.41	µg•L ⁻¹	<RDL	0.1	0.5
ECW03IN	11/6/2008 1:45	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW03IN	11/6/2008 1:45	Calcium, Total, ICP-MS	16000	µg•L ⁻¹		10	50
ECW03IN	11/6/2008 1:45	Chromium, Total, ICP-MS	0.34	µg•L ⁻¹	<RDL	0.2	1
ECW03IN	11/6/2008 1:45	Copper, Total, ICP-MS	2.92	µg•L ⁻¹		0.4	2
ECW03IN	11/6/2008 1:45	Hardness, Calc	54.5	CaCO3•L ⁻¹		0.066	0.331
ECW03IN	11/6/2008 1:45	Iron, Total, ICP-MS	280	µg•L ⁻¹		10	10
ECW03IN	11/6/2008 1:45	Lead, Total, ICP-MS	0.333	µg•L ⁻¹		0.075	0.1
ECW03IN	11/6/2008 1:45	Magnesium, Total, ICP-MS	3560	µg•L ⁻¹		10	50
ECW03IN	11/6/2008 1:45	Manganese, Total, ICP-MS	26.5	µg•L ⁻¹		0.1	0.5
ECW03IN	11/6/2008 1:45	Nickel, Total, ICP-MS	1.1	µg•L ⁻¹		0.1	0.5
ECW03IN	11/6/2008 1:45	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW03IN	11/6/2008 1:45	Total Nitrogen	0.792	mg•L ⁻¹	H	0.05	0.1
ECW03IN	11/6/2008 1:45	Total Phosphorus	0.0435	mg•L ⁻¹	H	0.005	0.01
ECW03IN	11/6/2008 1:45	Total Suspended Solids	1.8	mg•L ⁻¹		0.5	1
ECW03IN	11/6/2008 1:45	Zinc, Total, ICP-MS	5.92	µg•L ⁻¹		0.5	2.5
ECW03IN	11/6/2008 1:45	pH	7.13	pH	H		
ECW03IN	11/6/2008 1:45	pH, Field	6.5	pH			
ECW03IN	12/7/2008 8:16	Arsenic, Total, ICP-MS	0.867	µg•L ⁻¹		0.1	0.5
ECW03IN	12/7/2008 8:16	Cadmium, Total, ICP-MS	0.066	µg•L ⁻¹	<RDL	0.05	0.25
ECW03IN	12/7/2008 8:16	Calcium, Total, ICP-MS	22200	µg•L ⁻¹		10	50
ECW03IN	12/7/2008 8:16	Chromium, Total, ICP-MS	1.34	µg•L ⁻¹		0.2	1
ECW03IN	12/7/2008 8:16	Copper, Total, ICP-MS	6.89	µg•L ⁻¹		0.4	2
ECW03IN	12/7/2008 8:16	Hardness, Calc	76.9	CaCO3•L ⁻¹		0.066	0.331
ECW03IN	12/7/2008 8:16	Lead, Total, ICP-MS	1.22	µg•L ⁻¹		0.075	0.1
ECW03IN	12/7/2008 8:16	Magnesium, Total, ICP-MS	5240	µg•L ⁻¹		10	50
ECW03IN	12/7/2008 8:16	Manganese, Total, ICP-MS	242	µg•L ⁻¹		0.1	0.5

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW03IN	12/7/2008 8:16	Nickel, Total, ICP-MS	2.8	µg•L ⁻¹		0.1	0.5
ECW03IN	12/7/2008 8:16	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW03IN	12/7/2008 8:16	Total Nitrogen	0.956	mg•L ⁻¹	H	0.05	0.1
ECW03IN	12/7/2008 8:16	Total Phosphorus	0.11	mg•L ⁻¹	H	0.005	0.01
ECW03IN	12/7/2008 8:16	Total Suspended Solids	28.3	mg•L ⁻¹		0.9	1.9
ECW03IN	12/7/2008 8:16	Zinc, Total, ICP-MS	41.8	µg•L ⁻¹		0.5	2.5
ECW03IN	12/7/2008 8:16	pH	7.64	pH	H		
ECW03IN	12/7/2008 8:16	pH, Field	7.9	pH			
ECW03IN	12/11/2008 12:40	Fecal Coliform	1	CFU•100ml ⁻¹			
ECW03OUT	3/13/2008 12:55	Fecal Coliform	3	CFU•100ml ⁻¹			
ECW03OUT	3/7/2008 18:30	Antimony, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.5	2.5
ECW03OUT	3/7/2008 18:30	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.5	2.5
ECW03OUT	3/7/2008 18:30	Beryllium, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.2	1
ECW03OUT	3/7/2008 18:30	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.1	0.5
ECW03OUT	3/7/2008 18:30	Calcium, Total, ICP-MS	21500	µg•L ⁻¹	H	50	250
ECW03OUT	3/7/2008 18:30	Chromium, Total, ICP-MS	0.41	µg•L ⁻¹	<RDL,H	0.4	2
ECW03OUT	3/7/2008 18:30	Copper, Total, ICP-MS	3.15	µg•L ⁻¹	H	0.4	2
ECW03OUT	3/7/2008 18:30	Hardness, Calc	72	CaCO3•L ⁻¹	H	0.2	1.25
ECW03OUT	3/7/2008 18:30	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.2	1
ECW03OUT	3/7/2008 18:30	Magnesium, Total, ICP-MS	4430	µg•L ⁻¹	H	30	150
ECW03OUT	3/7/2008 18:30	Manganese, Total, ICP-MS	27.4	µg•L ⁻¹	H	0.2	1
ECW03OUT	3/7/2008 18:30	Nickel, Total, ICP-MS	1	µg•L ⁻¹	<RDL,H	0.3	1.5
ECW03OUT	3/7/2008 18:30	Selenium, Total, ICP-MS		µg•L ⁻¹	<MDL,H	1.5	7.5
ECW03OUT	3/7/2008 18:30	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.2	1
ECW03OUT	3/7/2008 18:30	Thallium, Total, ICP-MS		µg•L ⁻¹	<MDL,H	0.2	1
ECW03OUT	3/7/2008 18:30	Total Nitrogen	0.472	mg•L ⁻¹	H	0.05	0.1
ECW03OUT	3/7/2008 18:30	Total Phosphorus	0.0374	mg•L ⁻¹	H	0.005	0.01
ECW03OUT	3/7/2008 18:30	Total Suspended Solids	8	mg•L ⁻¹		0.5	1
ECW03OUT	3/7/2008 18:30	Zinc, Total, ICP-MS	2.2	µg•L ⁻¹	<RDL,H	0.5	2.5
ECW03OUT	3/7/2008 18:30	pH	7.87	pH	H		

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW03OUT	3/7/2008 18:30	pH, Field	6.8	pH			
ECW03OUT	5/19/2008 12:35	Fecal Coliform	1	CFU•100ml ⁻¹			
ECW03OUT	5/13/2008 13:00	Arsenic, Total, ICP-MS		µg•L ⁻¹	<MDL	0.5	2.5
ECW03OUT	5/13/2008 13:00	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.1	0.5
ECW03OUT	5/13/2008 13:00	Calcium, Total, ICP-MS	25700	µg•L ⁻¹		50	250
ECW03OUT	5/13/2008 13:00	Chromium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.4	2
ECW03OUT	5/13/2008 13:00	Copper, Total, ICP-MS	2.62	µg•L ⁻¹		0.4	2
ECW03OUT	5/13/2008 13:00	Hardness, Calc	88.9	CaCO3•L ⁻¹		0.2	1.25
ECW03OUT	5/13/2008 13:00	Lead, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
ECW03OUT	5/13/2008 13:00	Magnesium, Total, ICP-MS	6020	µg•L ⁻¹		30	150
ECW03OUT	5/13/2008 13:00	Manganese, Total, ICP-MS	15.7	µg•L ⁻¹		0.2	1
ECW03OUT	5/13/2008 13:00	Nickel, Total, ICP-MS	1.1	µg•L ⁻¹	<RDL	0.3	1.5
ECW03OUT	5/13/2008 13:00	Silver, Total, ICP-MS		µg•L ⁻¹	<MDL	0.2	1
ECW03OUT	5/13/2008 13:00	Total Nitrogen	0.42	mg•L ⁻¹	H	0.05	0.1
ECW03OUT	5/13/2008 13:00	Total Phosphorus	0.0195	mg•L ⁻¹	H	0.005	0.01
ECW03OUT	5/13/2008 13:00	Total Suspended Solids	3.8	mg•L ⁻¹		0.5	1
ECW03OUT	5/13/2008 13:00	Zinc, Total, ICP-MS	1.3	µg•L ⁻¹	<RDL	0.5	2.5
ECW03OUT	5/13/2008 13:00	pH	8.13	pH	H		
ECW03OUT	11/10/2008 13:00	Fecal Coliform	190	CFU•100ml ⁻¹			
ECW03OUT	11/6/2008 7:22	Arsenic, Total, ICP-MS	0.43	µg•L ⁻¹	<RDL	0.1	0.5
ECW03OUT	11/6/2008 7:22	Cadmium, Total, ICP-MS		µg•L ⁻¹	<MDL	0.05	0.25
ECW03OUT	11/6/2008 7:22	Calcium, Total, ICP-MS	9950	µg•L ⁻¹		10	50
ECW03OUT	11/6/2008 7:22	Chromium, Total, ICP-MS	0.39	µg•L ⁻¹	<RDL	0.2	1
ECW03OUT	11/6/2008 7:22	Copper, Total, ICP-MS	2.99	µg•L ⁻¹		0.4	2
ECW03OUT	11/6/2008 7:22	Hardness, Calc	34	CaCO3•L ⁻¹		0.066	0.331
ECW03OUT	11/6/2008 7:22	Iron, Total, ICP-MS	232	µg•L ⁻¹		10	10
ECW03OUT	11/6/2008 7:22	Lead, Total, ICP-MS	0.364	µg•L ⁻¹		0.075	0.1
ECW03OUT	11/6/2008 7:22	Magnesium, Total, ICP-MS	2220	µg•L ⁻¹		10	50
ECW03OUT	11/6/2008 7:22	Manganese, Total, ICP-MS	18.5	µg•L ⁻¹		0.1	0.5
ECW03OUT	11/6/2008 7:22	Nickel, Total, ICP-MS	1.09	µg•L ⁻¹		0.1	0.5

LOCATOR	COLLECTDATE	PARMNAME	NUMVALUE	UNITS	QUALIFIER	MDL	RDL
ECW03OUT	11/6/2008 7:22	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.05	0.25
ECW03OUT	11/6/2008 7:22	Total Nitrogen	0.766	$\text{mg}\cdot\text{L}^{-1}$	H	0.05	0.1
ECW03OUT	11/6/2008 7:22	Total Phosphorus	0.0454	$\text{mg}\cdot\text{L}^{-1}$	H	0.005	0.01
ECW03OUT	11/6/2008 7:22	Total Suspended Solids	2.8	$\text{mg}\cdot\text{L}^{-1}$		1	2
ECW03OUT	11/6/2008 7:22	Zinc, Total, ICP-MS	4.84	$\mu\text{g}\cdot\text{L}^{-1}$		0.5	2.5
ECW03OUT	11/6/2008 7:22	pH	7.16	pH	H		
ECW03OUT	11/6/2008 7:22	pH, Field	6	pH			
ECW03OUT	12/7/2008 13:50	Arsenic, Total, ICP-MS	0.43	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.1	0.5
ECW03OUT	12/7/2008 13:50	Cadmium, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.05	0.25
ECW03OUT	12/7/2008 13:50	Calcium, Total, ICP-MS	21600	$\mu\text{g}\cdot\text{L}^{-1}$		10	50
ECW03OUT	12/7/2008 13:50	Chromium, Total, ICP-MS	0.45	$\mu\text{g}\cdot\text{L}^{-1}$	<RDL	0.2	1
ECW03OUT	12/7/2008 13:50	Copper, Total, ICP-MS	4.04	$\mu\text{g}\cdot\text{L}^{-1}$		0.4	2
ECW03OUT	12/7/2008 13:50	Hardness, Calc	75.2	$\text{CaCO}_3\cdot\text{L}^{-1}$		0.066	0.331
ECW03OUT	12/7/2008 13:50	Lead, Total, ICP-MS	0.181	$\mu\text{g}\cdot\text{L}^{-1}$		0.075	0.1
ECW03OUT	12/7/2008 13:50	Magnesium, Total, ICP-MS	5160	$\mu\text{g}\cdot\text{L}^{-1}$		10	50
ECW03OUT	12/7/2008 13:50	Manganese, Total, ICP-MS	33.2	$\mu\text{g}\cdot\text{L}^{-1}$		0.1	0.5
ECW03OUT	12/7/2008 13:50	Nickel, Total, ICP-MS	1.33	$\mu\text{g}\cdot\text{L}^{-1}$		0.1	0.5
ECW03OUT	12/7/2008 13:50	Silver, Total, ICP-MS		$\mu\text{g}\cdot\text{L}^{-1}$	<MDL	0.05	0.25
ECW03OUT	12/7/2008 13:50	Total Nitrogen	0.568	$\text{mg}\cdot\text{L}^{-1}$	H	0.05	0.1
ECW03OUT	12/7/2008 13:50	Total Phosphorus	0.0408	$\text{mg}\cdot\text{L}^{-1}$	H	0.005	0.01
ECW03OUT	12/7/2008 13:50	Total Suspended Solids	7	$\text{mg}\cdot\text{L}^{-1}$		0.5	1
ECW03OUT	12/7/2008 13:50	Zinc, Total, ICP-MS	6.67	$\mu\text{g}\cdot\text{L}^{-1}$		0.5	2.5
ECW03OUT	12/7/2008 13:50	pH	7.75	pH	H		
ECW03OUT	12/7/2008 13:50	pH, Field	7.7	pH			
ECW03OUT	12/11/2008 13:10	Fecal Coliform	4	$\text{CFU}\cdot 100\text{ml}^{-1}$			