WRIA 8 Technical Memorandum 2011-01

# Lake Washington/ Cedar/Sammamish Watershed (WRIA 8) Land Cover Change Analysis

July 2011

King County

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Water and Land Resources Division
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# Lake Washington/ Cedar/Sammamish Watershed (WRIA 8) Land Cover Change Analysis

**Prepared for:**

Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Technical Committee

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**Funded by**

Puget Sound Partnership through an EPA National Estuary Grant administered by the Washington State Recreation and Conservation Office (RCO Grant #09-1546)

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

# Acknowledgements

We would like to thank members of the WRIA 8 Implementation and Technical Committees as well as Jonathan Frodge, Kate O'Laughlin, Gino Lucchetti and Nate Herold for insights during the process of writing this report. This project was funded by the Puget Sound Partnership through an EPA National Estuary Grant administered by the Washington State Recreation and Conservation Office (RCO Grant #09-1546).

# Citation

Vanderhoof, J., S. Stolnack, K. Rauscher, and K. Higgins. 2011. Lake Washington/ Cedar/ Sammamish Watershed (WRIA 8) Land Cover Change Analysis. Prepared for WRIA8 Technical Committee by King County Water and Land Resources Division, Department of Natural Resources and Parks. Seattle, Washington.

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# EXECUTIVE SUMMARY

In 2010, the Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Technical Committee commissioned King County staff to conduct a land cover change analysis in order to answer two broad questions:

1. Is forest cover being retained in priority WRIA 8 subbasins?
2. Are riparian buffers being protected along priority streams inside WRIA 8?

With those questions in mind, we used existing satellite imagery and aerial photography to quantify the following indicators:

1. Change in total forest cover area in WRIA 8, by subbasin (1991-1996, 1996-2001, 2001-2006, and 1991-2006)
2. Change in developed area in WRIA 8, by subbasin (1991-1996, 1996-2001, 2001-2006, and 1991-2006)
3. Change in forest cover and impervious area within riparian areas in priority WRIA 8 subbasins (2005-2009)

### Landscape Scale Analyses

For the broadest spatial scale under analysis, LandSat land cover classifications (30-meter resolution) covering WRIA 8 for the years 1991, 1996, 2001 and 2006 were obtained from the NOAA Coastal Change Analysis Program (C-CAP). We calculated total acreage and percentage of each subbasin classified as "forest" (evergreen, deciduous, or mixed) for each of the data years, then determined the amount of acreage and percentage change in forest cover over the periods. In addition, datasets depicting land cover change for each LandSat "pixel" between the periods (1991-1996, 1996-2001, and 2001-2006) were also downloaded from the same source. We examined changes in forest cover by WRIA 8 priority area (Tiers 1, 2, and 3 in WRIA 8 nomenclature), by subbasin, and inside vs. outside the Urban Growth Area boundary.

Given the importance of coniferous tree species to the ecology of the Puget Sound region, we performed a separate analysis of the change in the "evergreen" forest classification for each of the four data years.

Also at the LandSat spatial scale, we conducted two assessments of changes to the built environment between 1991 and 2006. First, we assessed changes in "developed area" classifications using C-CAP data. "Developed area" as used in this report is defined as the sum of five land cover classes: bare land, developed open space, and high-density, medium-density, and low-density developed (see Appendix A for definitions). Second, we used estimates of actual impervious surface area to estimate change in that variable over time.

### Stream Reach Scale Analyses

In those subbasins showing the greatest percentage of forest cover loss between 2001 and 2006 using C-CAP data, we selected a random sample of stream reaches for closer examination. This component of the study was performed at a finer spatial scale than the forest cover analysis in

order to estimate change in areas closest to WRIA 8 streams with greater confidence. High resolution aerial photographs (1-foot or greater resolution) were used in this portion of the project. In total, we analyzed 54 stream reaches comprising about 22 percent of the salmon-bearing stream length in each subbasin analyzed in this part of the study.

**Results**

*Landscape-scale Analyses.* **Our analyses showed a decline in forest cover in 42 of 47 WRIA 8 subbasins between 1991 and 2006.** In Tier 1 subbasins the greatest forest cover loss over the study period was in North Fork Issaquah (-30.1 percent), Upper Sammamish Valley (-15.3 percent), and Lower Bear (-11.4 percent). In Tier 2 subbasins, the greatest loss of forest cover between 1991 and 2006 occurred in Upper North (-24.8 percent), Lower North (-24.4 percent), Evans (-12.7 percent), and Little Bear (-12.0 percent).[1] Seven Tier 3 subbasins saw forest cover decline by more than 10 percent over the same period (Cedar North Urban, Upper Swamp, East Lake Sammamish, Cedar South Urban, Lower Swamp, Coal, and West Lake Sammamish).

**In aggregate, the majority of forest cover loss between 1991 and 2006 occurred where land conversion is expected, inside the Urban Growth Area (UGA) boundaries** (-20.5 percent in Tier 1 areas and -23.5 percent in Tier 2 areas inside the UGA). Forest cover change in aggregate outside the UGA boundaries was too small to reliably determine (-1 percent and +2.9 percent in Tier 1 and Tier 2 areas, respectively).

The most recent period (2001-2006) saw a slower pace of loss in forest cover in most subbasins when compared to earlier periods. This decline in the amount of change may be influenced by a number of potential factors, including stronger measures protecting forest cover, a declining relative amount of forest to lose (the rate of forest conversion declines as an area approaches buildout), or a weaker economic climate compared to earlier periods. The East Fork Issaquah and Lower North subbasins were two of the exceptions to this trend, as these areas saw increases in rate of change during 2001-2006. As in most areas in the watershed, the majority of forest cover loss in these two subbasins during this period occurred where land conversion is directed – inside the UGA boundaries.

**All subbasins in WRIA 8 showed an increase in developed area from 1991 to 2006.** Similar to the slowed trend in forest loss, the trend of increase in developed area slowed in the most recent time period (2001-2006). In Tier 1 subbasins, the average extent of developed area during these periods went from 33 percent to 37 percent, but the rate of gain in developed area dropped from an average of 21 acres per year in the 1991-1996 period to 16 acres per year in the 2001-2006 period. The Tier 2 subbasin average developed area during these periods went from 41 percent to 46 percent, but the gain in developed area dropped from an average of 32 acres per year in the 1991-1996 period to 25 acres per year in the 2001-2006 period. Trends were similar in Tier 3 as well: subbasin average developed area increased from 62 percent to 66 percent, and

[1] Although the 195-acre Mercer Slough Subbasin saw an 18.8 percent decline in forest cover between 1991 and 2006, the actual amount of forest cover loss in that subbasin was only 4 acres.

the gain in developed area dropped from an average of 22 acres per year in the 1991-1996 period to 12 acres per year in the 2001-2006 period.

*Reach-scale Analyses*. **The amount of impervious area inside the riparian area (for this analysis, defined as the area within 165 feet of the stream) increased between 2005 and 2009 in nearly all subbasins we studied.** The greatest increase in impervious area in the reaches we studied was observed in Lower Bear (21.0 percent), followed by Evans (10.4 percent) and Lower North (7.2 percent).

**Forest cover loss was not consistent across basins**: Of the eight subbasins we sampled at this scale, three showed an overall loss in forest cover in the riparian area between 2005 and 2009 (Lower Bear, Evans, and Upper North), whereas five showed either no appreciable change or a small gain in forest cover (East Fork Issaquah, North Fork Issaquah, Upper Bear, Cedar North Rural, and Lower North). Reaches inside the UGA experienced an overall 3.4 percent loss of forest cover between 2005 and 2009, whereas reaches outside the UGA saw a 1.5 percent loss of forest cover during the same period. Impervious area inside the UGA increased by 10.5 percent, whereas outside the UGA impervious area increased by 5.3 percent.

**Conclusions**

Although the continued loss of forest cover inside the UGA is predictable because development is directed into those areas, the riparian area analysis shows that some riparian areas lost forest cover and all gained impervious cover between 2005 and 2009 despite existing regulations designed to protect these environmentally sensitive critical areas. Although it was beyond the scope of this project to investigate the particular reasons for forest cover loss and impervious cover gain in these potentially important ecological areas, much of the change appeared to be the result of two phenomena: (1) small actions by many individual private landowners, and (2) at least one larger development project constructed under ‘vested’ development rules (and therefore not subject to the most recent critical areas protections).

These observations suggest at least two categories of actions that might be useful to improve protection of riparian areas as part of a larger strategy: (1) targeted outreach activities focused on improving stewardship of stream areas on private property, and (2) activities geared toward identifying important riparian areas subject to vested development rights, and working with property owners to find acceptable means of protecting and improving riparian function in those areas.

# 1.0. INTRODUCTION

In the Lake Washington/Cedar/Sammamish Watershed (a.k.a., Water Resource Inventory Area 8, or WRIA 8), the protection of existing, intact forest cover is considered to be one of the most important actions to take to conserve salmon (WRIA 8 SRC 2005). Intact forests contribute to natural watershed processes and high water quality necessary for salmon survival, and therefore should be maintained in areas important to those species. In areas where forest cover is absent or cannot be maintained, the protection and restoration of riparian buffers (i.e., forested streamside areas) is considered especially important.

As part of WRIA 8 Chinook Conservation Plan implementation monitoring and assessment, the WRIA 8 Technical Committee commissioned King County staff in 2010 to conduct a land cover change analysis in order to answer two broad questions:

1. Is forest cover being retained in priority watersheds?
2. Are riparian buffers being protected along priority streams?

The objectives of this project are to quantify the following indicators:

1. Change in total forest cover area in WRIA 8, by subbasin (1991-1996, 1996-2001, 2001-2006, and 1991-2006)
2. Change in developed area in WRIA 8, by subbasin (1991-1996, 1996-2001, 2001-2006, and 1991-2006)
3. Change in forest cover and impervious area within riparian areas in priority WRIA 8 subbasins (2005-2009)

The geographic scope of the project is the Lake Washington/Cedar/Sammamish Watershed (WRIA 8 – Figure 1). Funding was provided by the Puget Sound Partnership through a grant from the U.S. EPA National Estuary Program, with project oversight by the WRIA 8 Technical Committee. Preliminary results from these analyses were reported at the WRIA 8 5-Year Chinook Conservation Plan Implementation Summit on December 3, 2010.

Technical analyses contributing to the 2005 WRIA 8 Chinook Conservation Plan included a process in which subbasins were prioritized by "Tiers" to ensure that conservation strategies were appropriate for each area (see Technical Appendix C-2 of the Plan: Leonetti et al. 2005; see also Figures 1 through 3):

- Tier 1 subbasins are core spawning and obligatory rearing and migratory areas for Chinook salmon without which the WRIA 8 populations could not complete their life cycle. While migratory areas may traverse heavily urbanized sections of the watershed, the majority of Tier 1 spawning and rearing areas lie in rural areas outside the Urban Growth Area (UGA) boundary, and contain large zones of intact forest.
- Tier 2 subbasins contain less frequent Chinook spawning areas with moderate to high relative watershed condition. These subbasins are considered crucial for maintaining and improving the spatial structure of Chinook populations in WRIA 8. Tier 2 subbasins include episodic production areas that contain limited favorable habitat for Chinook salmon, but which could be productive for the species in the future given greater Chinook salmon abundance and protection of the existing higher watershed condition. These areas lie both inside and outside the UGA boundary.

- Tier 3 subbasins exhibit lower watershed function, significantly impaired watershed processes, and degraded aquatic habitat. They also tend to possess naturally limited production and abundance of Chinook salmon, based on subbasin size, channel width, gradient, or length of suitable habitat area. Tier 3 areas lie mostly inside the UGA boundary.

**Figure 1. Lake Washington/Cedar/Sammamish Watershed (WRIA 8) map.**

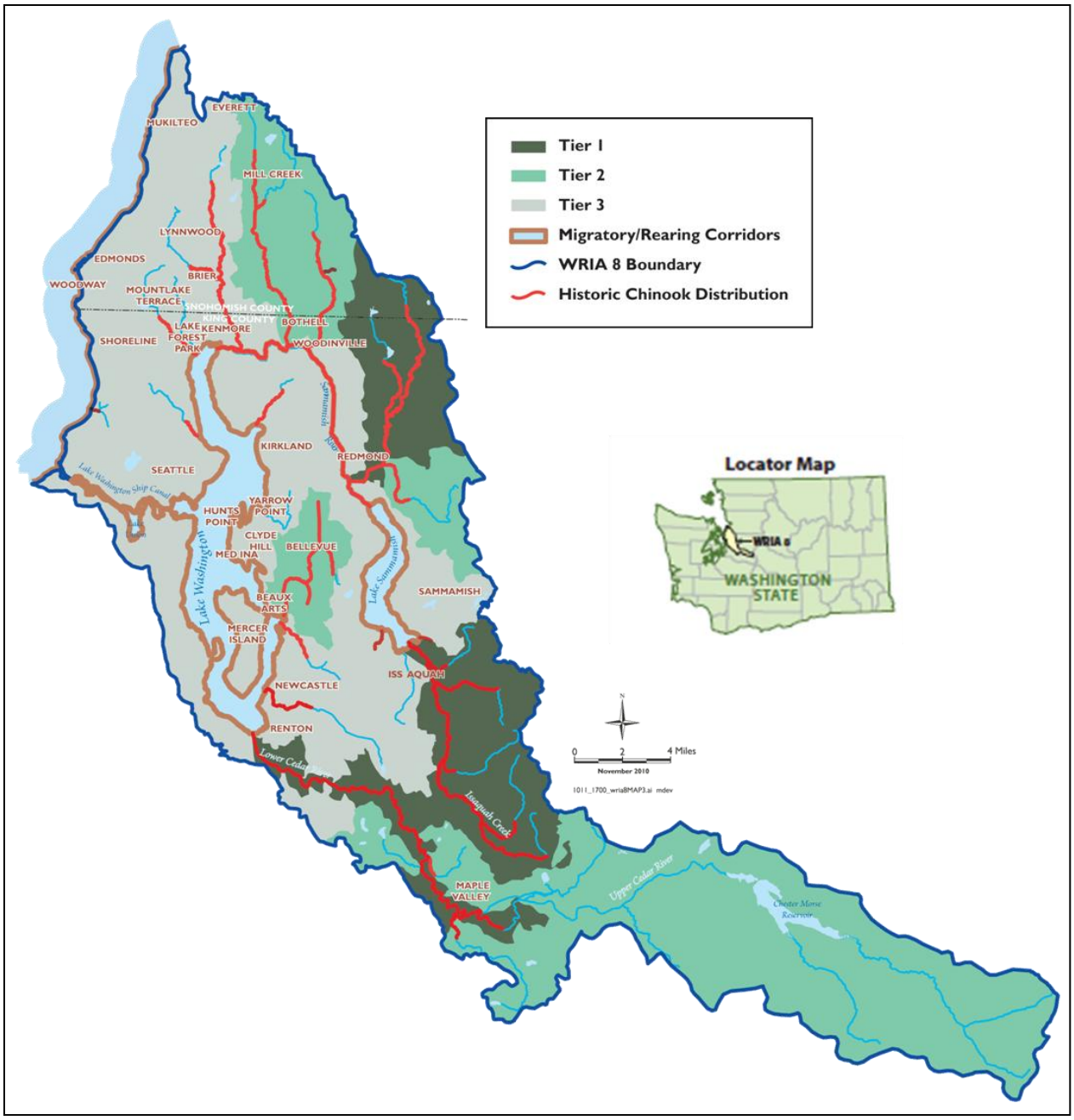

**Figure 2. Urban Growth Area (UGA) boundary in WRIA 8, 2010.**

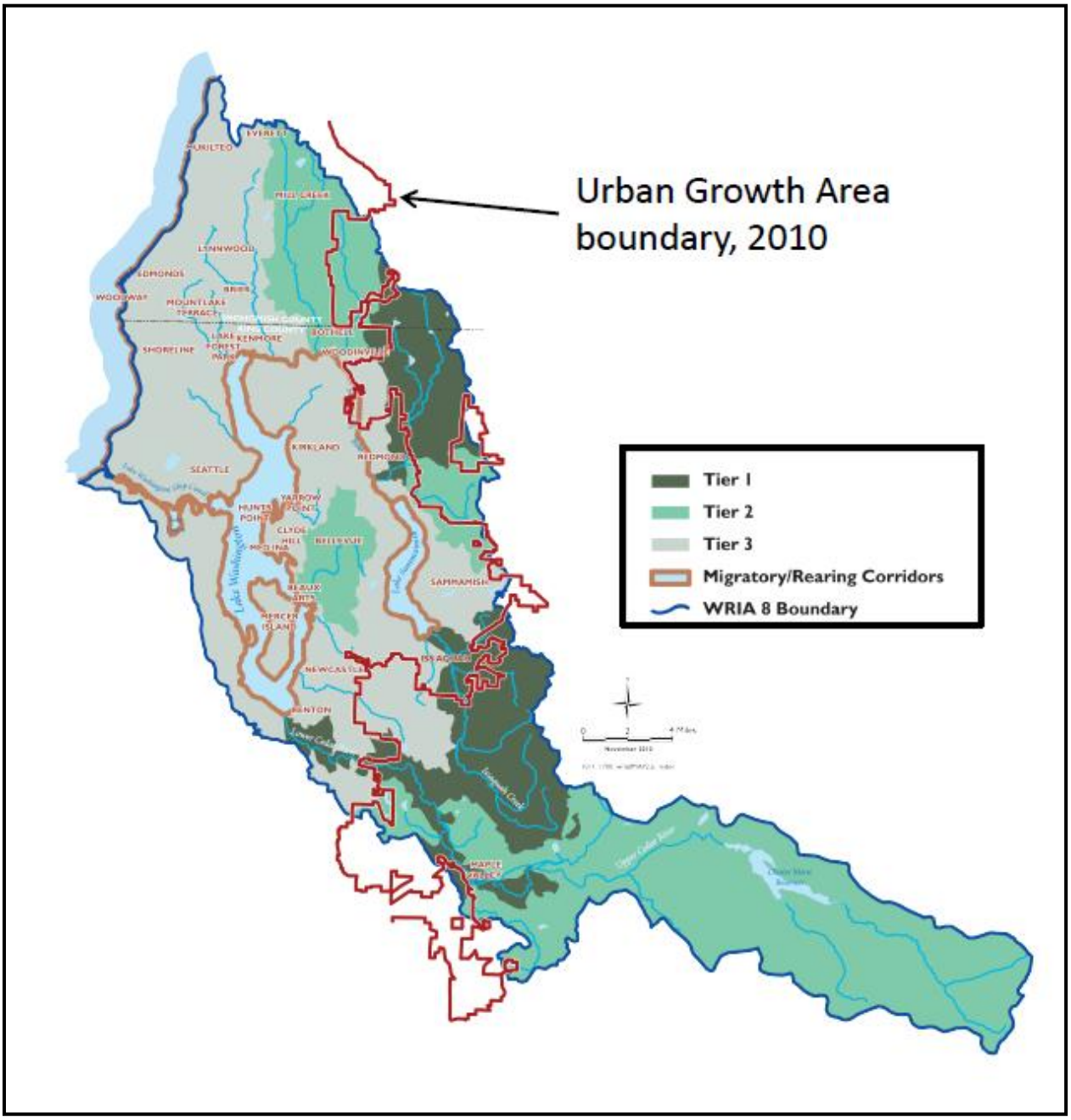

**Figure 3. Subbasins analyzed in WRIA 8 shown by their Tier ranking.** Subbasin names are listed in Table 1.

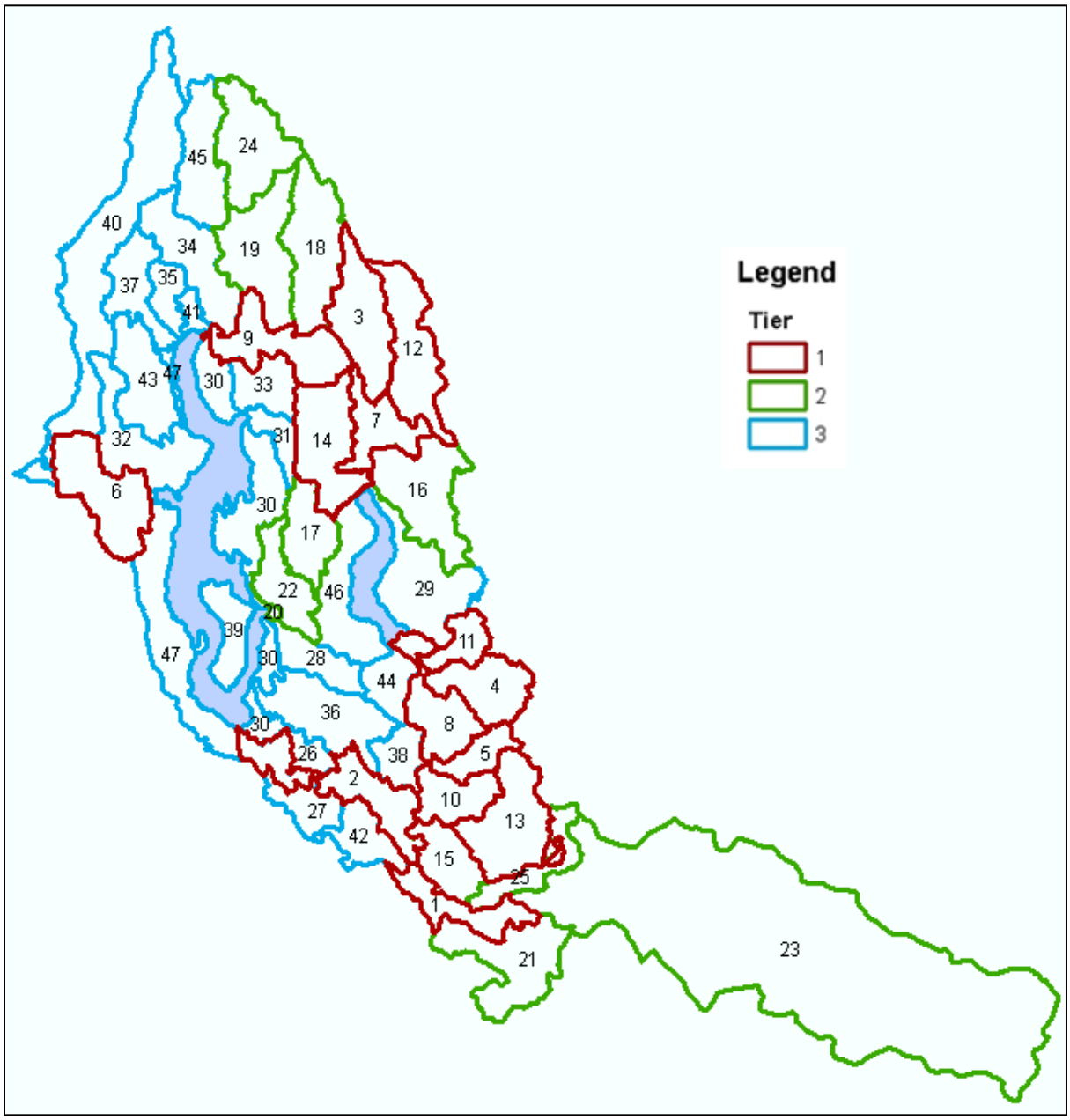

**Table 1. Subbasins in WRIA 8 and identified in Figure 3.**

| ID | SUBBASIN | Tier |
|---|---|---|
| 1 | Cedar Main Rural | 1 |
| 2 | Cedar Main Urban | 1 |
| 3 | Cottage Lake | 1 |
| 4 | East Fork Issaquah | 1 |
| 5 | Fifteenmile | 1 |
| 6 | Lake Union | 1 |
| 7 | Lower Bear | 1 |
| 8 | Lower Issaquah | 1 |
| 9 | Lower Sammamish Valley | 1 |
| 10 | Middle Issaquah | 1 |
| 11 | North Fork Issaquah | 1 |
| 12 | Upper Bear | 1 |
| 13 | Upper Issaquah | 1 |
| 14 | Upper Sammamish Valley | 1 |
| 15 | Cedar North Rural | 2 |
| 16 | Evans | 2 |
| 17 | Kelsey | 2 |
| 18 | Little Bear | 2 |
| 19 | Lower North | 2 |
| 20 | Mercer Slough | 2 |
| 21 | Rock | 2 |
| 22 | South Kelsey | 2 |
| 23 | Upper Cedar | 2 |
| 24 | Upper North | 2 |
| 25 | Walsh | 2 |
| 26 | Cedar North Urban | 3 |
| 27 | Cedar South Urban | 3 |
| 28 | Coal | 3 |
| 29 | East Lake Sammamish | 3 |
| 30 | East Lake Washington | 3 |
| 31 | Forbes | 3 |
| 32 | Green Lake | 3 |
| 33 | Juanita | 3 |
| 34 | Lower Swamp | 3 |
| 35 | Lyons | 3 |
| 36 | May | 3 |
| 37 | McAleer | 3 |
| 38 | McDonald | 3 |
| 39 | Mercer Island | 3 |
| 40 | Nearshore | 3 |
| 41 | North Lake Washington | 3 |
| 42 | Peterson | 3 |
| 43 | Thornton | 3 |
| 44 | Tibbetts | 3 |
| 45 | Upper Swamp | 3 |
| 46 | West Lake Sammamish | 3 |
| 47 | West Lake Washington | 3 |

# 2.0. METHODS

The subbasins and tiers used in this analysis are identical to those used in the Lake Washington /Cedar /Sammamish Chinook Salmon Conservation Plan Technical Appendix C-2 (Leonetti et al. 2005). Although data on hydrologic boundaries have improved since the time of that analysis, we used subbasin boundaries consistent with Leonetti et al. (2005), which were based on Hartley (2001), to allow comparison between the two investigations.

## 2.1 Basin-wide Analyses

LandSat land cover classifications covering WRIA 8 for the years 1991, 1996, 2001, and 2006 were downloaded from NOAA's Coastal Change Analysis Program (C-CAP) website,[2,3] then re-projected from Albers Conical Equal Area to Washington State Plane North projection. Land cover in these datasets was classified at a resolution of $30m^2$ pixels. WRIA 8 is covered by a single LandSat pathrow footprint (Path 46, Row 27). Given the difficulty of obtaining cloud-free imagery, data collection spans a range of dates for a given year (Table 2).

**Table 2. LandSat data collection date ranges.**

| Study year | Dates orthophotos were taken |
|---|---|
| 1991 | 7/7/1991 to 9/3/1991 (exact date not provided) |
| 1996 | 8/21/1996 |
| 2001 | 7/7 and 9/25/2000; 5/31/2001 |
| 2006 | 9/2/2006 |

Three datasets depicting land cover change between periods were also downloaded from C-CAP: 1991-1996, 1996-2001, and 2001-2006. Additionally, King County Water and Land Resources Division GIS staff created a dataset depicting change for 1991-2006. These four "change" datasets allow the user to analyze location-specific changes between two given eras of classifications. Methods for establishing the original C-CAP land cover classifications are described in Dobson et al. (1995). The C-CAP program modified land cover classes since they were originally established in 1995; the classes now in use (and used in this report) are listed in Appendix A.[4] Note that cover classes used by C-CAP vary considerably from the classification system used in Leonetti et al. (2005). Therefore, comparisons between their study and this one should be undertaken with caution. Additional discussion of the differences in classification systems is included in Appendix B.

The total area in the 47 subbasins analyzed for WRIA 8 is 388,285 acres. An extra 26,660 acres comprising lakes Washington and Sammamish were removed from all analyses.

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[2] http://www.csc.noaa.gov/crs/lca/pacificcoast.html

[3] At the time of this analysis, the year 2006 is the latest year for which NOAA classifications are available.

[4] Out of 24 possible land cover categories in the C-CAP characterization scheme, 20 were present in the WRIA 8 subbasins (see Appendix A). Also see http://www.csc.noaa.gov/digitalcoast/data/ccapregional/_pdf/ccap_class_scheme.pdf

Overall accuracy of the C-CAP classification process is estimated at 86.1 percent and 85.0 percent Kappa (NOAA 2004). The accuracy results shown below are from a combined accuracy assessment completed on both Oregon and Washington C-CAP areas. A total of 1043 assessment points were located in Washington and 1165 points were located in Oregon.

Each class accuracy is as follows: (Errors of Omission/Commission)

0 Background (N/A)
1 Unclassified (Cloud, Shadow, etc)(N/A)
2 High Intensity Developed (50%/73%)
3 Medium Intensity Developed (79%/52%)
4 Low Intensity Developed (25%/41%)
5 Open Spaces Developed (50%/100%)
6 Cultivated Land (86%/72%)
7 Pasture/Hay (77%/73%)
8 Grassland (61%/76%)
9 Deciduous Forest (95%/88%)
10 Evergreen Forest (99%/85%)
11 Mixed Forest (80%/93%)
12 Scrub/Shrub (75%/84%)
13 Palustrine Forested Wetland (75%/75%)
14 Palustrine Scrub/Shrub Wetland (68%/84%)
15 Palustrine Emergent Wetland (91%/72%)
16 Estuarine Forested Wetland (N/A)
17 Estuarine Scrub/Shrub Wetland (N/A)
18 Estuarine Emergent Wetland (93%/100%)
19 Unconsolidated Shore (90%/95%)
20 Bare Land (79%/96%)
21 Water (100%/100%)
22 Palustrine Aquatic Bed (100%/100%)
23 Estuarine Aquatic Bed (100%/100%)
24 Tundra (N/A)
25 Snow/Ice (N/A)

### 2.1.1 Forest Cover

The total acreage and percentage of each subbasin classified as forest (evergreen, deciduous, and mixed) was calculated for each of the four data years.

Using total forest acreage and percentage of each subbasin, we then calculated the percent change in forest cover per subbasin between each time period. To calculate percent change, the following formula was used:

Percent change = ((y2 - y1) / y1)*100

A positive or negative number represents the direction of forest cover change: percent change where forest cover has decreased will be indicated by a negative number, and for those areas where forest cover is increasing, the percent change will be positive.

Since land management activities may differ depending on regulatory mandates (e.g., the Washington Growth Management Act), we chose to examine the difference in forest cover inside

versus outside the Urban Growth Area. For this component of the analysis, forest cover acreage was calculated for each subbasin and sub-categorized according to inside or outside the growth boundary.

#### Evergreen Forest

Given the importance of coniferous species to the ecology of the Puget Sound region (e.g., Kruckeberg 1991), the WRIA 8 Technical Committee suggested that the extent of evergreen forest (rather than combined evergreen, deciduous and mixed classifications) may be a more useful indicator of natural watershed conditions in WRIA 8; therefore, we performed a separate analysis of the change in evergreen forest for each of the four data years. As in the previous analysis, areas inside and outside the urban growth boundary were assessed for each subbasin separately as well as collectively.

#### Forest Conversion

In order to examine forest cover converted to developed land, change in total acreage for the following land cover classes was calculated by subbasin (using the land cover change datasets) for 1991-1996, 1996-2001, and 2001-2006:

- Deciduous Forest to Bare Land
- Deciduous Forest to Developed Open Space
- Deciduous Forest to High Intensity Developed
- Deciduous Forest to Low Intensity Developed
- Deciduous Forest to Medium Intensity Developed
- Evergreen Forest to Bare Land
- Evergreen Forest to Developed Open Space
- Evergreen Forest to High Intensity Developed
- Evergreen Forest to Low Intensity Developed
- Evergreen Forest to Medium Intensity Developed
- Mixed Forest to Bare Land
- Mixed Forest to Developed Open Space
- Mixed Forest to High Intensity Developed
- Mixed Forest to Low Intensity Developed
- Mixed Forest to Medium Intensity Developed

### 2.1.2 Development

Two different approaches to examining development were used in this study: lands classified as developed in C-CAP ("Developed Area") and estimated impervious area ("Impervious Area"), regardless of the land classification.

#### Developed Area

"Developed area" as used in this report is defined as the sum of five land cover classes: bare land, developed open space, and high-density, medium-density, and low-density developed (see Appendix A for definitions). We calculated percent, total area, and rate of change in developed area.

### Impervious Area

Estimates of actual impervious surface area were obtained from raster files from the Washington Department of Ecology (WDOE).[5] Impervious area was estimated by WDOE as a continuous variable from a combination of LandSat and higher resolution imagery using Regression Tree modeling methods as in Yang et al. (2003). Only the 2006 dataset included pixels with less than 20 percent impervious; therefore, we removed those pixels to make comparisons across all study years possible. Each remaining pixel in the 1991, 1996, 2001 and 2006 datasets (containing values from 20 to 100 percent) was subsequently converted to impervious acres per pixel. Acreage was then summed by subbasin for each period.

## 2.2 Riparian Area

The riparian analysis component of this study was performed at a finer scale than the forest cover analysis in order to analyze change in the riparian zone with greater confidence. The C-CAP LandSat data were characterized at a $30m^2$ resolution; the riparian land cover in this portion of the study, on the other hand, was characterized at a $10m^2$ resolution (Figure 4). The assumption

**Figure 4. Riparian grid-squares (left) and C-CAP land cover at the idential location.**

[5] http://www.ecy.wa.gov/services/gis/data/landcover/landcover.htm

for using this approach separate from the C-CAP data is that the higher-resolution orthophotos would help produce more accurate information about what is occurring in riparian areas.

The years 2005 and 2009 were chosen for analysis for two reasons. First, 2005 was the year the WRIA 8 Plan was ratified, which serves as a baseline for future analyses of buffer change; and second, high quality, orthorectified aerial photographs were readily available in the King County GIS for all basins under consideration for those years. Earlier orthophotos were available (e.g., 2000), but resolution[6] was insufficient for reliable classification at this level of detail.

Because of time and budget constraints, only a subset of WRIA 8 subbasins could be examined. A set of filters was applied to determine which subbasins would be analyzed for riparian cover. The subset of subbasins was selected from:

1. Tier 1 or Tier 2 subbasins – i.e., the areas considered most important overall for Chinook salmon recovery.
2. Basins with the highest percent decrease in overall forest cover in the most recent C-CAP study period (2001-2006).

Given these criteria, we selected the top nine subbasins for further analysis (Table 3). One of those nine – the Upper Issaquah subbasin – was removed from subsequent analyses because its land use history is dissimilar to the other eight. Unlike the other subbasins meeting the above requirements, in which the dominant factor in forest cover loss is conversion for development, forest cover change in the Upper Issaquah subbasin during the overall period of study was mostly the result of ongoing timber harvest rotations. Also unlike the other eight subbasins, the previous two periods showed increases in forest cover in the Upper Issaquah subbasin, as older areas that had been harvested in prior periods grew into mature forest.

**Table 3. Subbasins selected for riparian area characterization, including percent change of forest in the subbasin between 2001 and 2006.**

| Tier | Subbasin | Subbasin Size (acres) | 2006 % Forest | % change 2001 to 2006 | stream miles under consideration | # of reaches to randomly select in basin |
|---|---|---|---|---|---|---|
| 1 | Lower Bear | 5222 | 31 | 2.23 | 14.0 | 10 |
| 1 | East Fork Issaquah | 6054 | 82 | 2.02 | 6.3 | 5 |
| 1 | North Fork Issaquah | 2947 | 43 | 12.53 | 2.0 | 1 |
| 1 | Upper Bear | 8860 | 63 | 1.87 | 10.3 | 8 |
| 1 | Upper Issaquah* | 9568 | 76 | 2.66 | 10.7 | -- |
| 2 | Cedar North Rural | 4809 | 48 | 1.81 | 4.0 | 3 |
| 2 | Evans | 9802 | 41 | 3.30 | 11.4 | 8 |
| 2 | Lower North | 9750 | 27 | 12.11 | 13.1 | 10 |
| 2 | Upper North | 8666 | 19 | 5.38 | 12.4 | 9 |

* Upper Issaquah was excluded from the analysis because of its land-use history, which is discussed further in the text.

[6] 2005 orthophotos were acquired in July 2005 at a resolution of 1-foot, and 2009 orthophotos were acquired April through October of that year at a resolution of 0.5-foot.

Of the 8 subbasins selected for analysis, reaches to be characterized were selected randomly from a subset of all stream reaches within the subbasin identified as actual or potential habitat for Chinook and coho salmon.[7] Stream (line) data were checked against 2009 aerial imagery to ensure the channel in the line file matched the channel in the 2009 imagery. The streams were divided into 500-meter segments (or smaller if the last segment in a reach was shorter than 500 meters) and then reaches were randomly selected for characterization.

Reach selection was proportionate to the length of salmonid-bearing streams in the subbasin, so that about 22.8 percent of total Chinook-coho stream miles in each subbasin were sampled. A total of 54 sets of 500-meter reaches (2 photo years per set) were examined (Figure 5).

For each of the 54 reaches, a stationary set of $10m^2$ grid squares was established in GIS to encompass 200 feet on each side of the stream. The 200-foot buffer width was chosen to ensure a wide enough area was characterized to be able to account for any regulatory buffer width applicable in the area. Subsequent analyses were performed at two spatial extents: (1) maximum regulatory buffer width required for any WRIA 8 stream (165 feet) and (2) current regulatory buffer width for the stream segment analyzed, if the segment resides in a jurisdiction requiring less than 165 feet.

Land cover for each $10m^2$ grid square was classified by hand using ArcMap and high-resolution orthophotos with resolution of 1 foot or greater. A scale of 1:1000 was used in ArcMap when classifying the grid squares. Grid squares were classified according to the dominant land cover found in a given square.[8]

Five land cover classifications were used:

1. Forest
2. Shrub
3. Building/all other impervious/roads, including gravel roads
4. Water
5. All other pervious (grass, lawn, mud, reed canarygrass, gravel pit, etc.)

Orthophotos in 2005 compared to 2009 aerial imagery were not always taken at the same angle or registered well when the separate 2009 photos were combined in mosaic. In Upper North Creek, reach 25, the 2005 orthophoto was spliced poorly in the middle of the reach. The effect of the splice was to lose two lanes of a road, which were roughly the equivalent of a row of 10m squares. In order to accommodate for this problem, the characterization boxes for 2005 were shifted to try to match the photo, and squares in the “lost” row were assumed to all be impervious, as they were accounting for the part of the road that was spliced out.

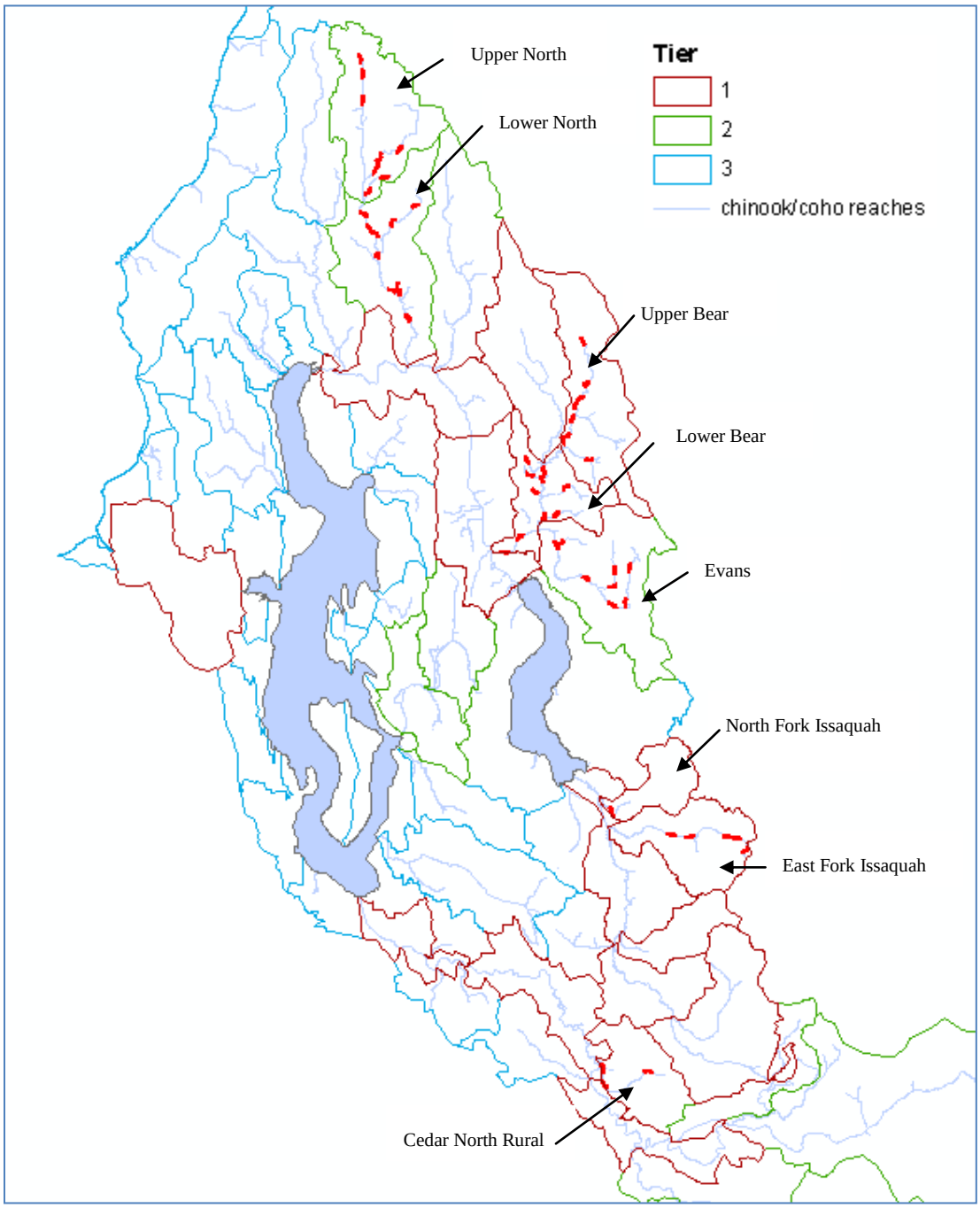
[7] King County GIS data.

[8] Where each set of grid squares meet at the upstream and downstream ends of a 500-meter reach, there is a small area of overlap. This overlap occurs because the end-point of one reach and the start-point of the next reach occurs within a grid square. Therefore, each reach includes a small portion of the adjacent upstream and downstream reach; in those cases were adjacent reaches were selected as part of the random sample, the data include this small amount of land cover duplication. This overlap occurred eight times in the study (once each in East Fork Issaquah and Evans Creek, and twice each in Upper Bear, Lower North, and Upper North).

Also in Upper North Creek, the 2005 orthophotos for reach 36 were skewed to such an extreme extent that the only way to perform a relatively equitable comparison to 2009 was to move the grid squares.

Most reaches characterized had some degree of photo shift. Care was taken so that changes in total amount of impervious area reflect a true change, and not just a shift in photo. This level of care was taken to ensure that the results do not render a false positive change in impervious area.

**Figure 5. Reaches (shown in red) randomly selected for land cover class characterization.**



# 3.0. RESULTS

## 3.1 Basin-wide Data

Tables showing results for the LandSat-scale analyses are extensive and often comprise one or two full pages. Because of their large size, all tables showing data for all 47 subbasins or other large tables are located in Appendix C. Smaller results tables are included in the main body of this chapter.

### 3.1.1 Forest Cover

The total acreage and percentage of each subbasin classified as forest (combined evergreen, deciduous, and mixed classifications) are presented in Appendix C, Table C-1, along with the percent change between each analysis period and for the entire time period (1991-2006). Overall, forest cover declined by 4.8 percent in Tier 1 subbasins, declined by 0.1 percent in Tier 2 subbasins, and declined by 10.4 percent in Tier 3 subbasins between 1991 and 2006 (Table 4). The protected Upper Cedar Subbasin comprises about 67,000 forested acres, or 78 percent of the Tier 2 forest cover, and saw a 3.7 percent increase in forest cover over the period. Removing this subbasin from our change analysis showed forest cover in the rest of Tier 2 subbasins declined by 8.4 percent between 1991 and 2006. The most recent period (2001-2006) generally saw a decline in percent change from previous periods (Table C-2, Appendix C). The Tier 1 subbasin showing the greatest percent change across the entire period from 1991 to 2006 was North Fork Issaquah, which went from 62 percent of the basin classified as forest to 43 percent. Nearly all the change in the North Fork Issaquah Creek subbasin was located inside the Urban Growth Area boundary. The Tier 1 subbasin with the highest percentage of forest cover showed little change over time: Fifteenmile went from 90 percent forest in 1991 to 89 percent in 2006 (well within detection limits of the C-CAP classification). Tier 2 subbasins Rock and Upper Cedar both gained forest cover from 1991 to 2006; however, most Tier 2 subbasins had about 50 percent forest cover or less in 1991 and lost more forest over time.

Table C-3a and C-3b in Appendix C presents forest area and percent of basin separated into the urban and rural areas. These data are summarized below in Table 4. Some subbasins are fully within either the urban or rural area, but for those subbasins that include parts of each, the results are separated to illustrate more specifically what is occurring in the urban or urbanizing versus rural portions of the subbasin. Tables C-3a and C-3b present the same information but in different ways: Table C-3a displays all data for a given subbasin in a single line, whereas Table C-3b segregates the urban and rural data. Tables C-3a and b illustrate, for example, that the Rock Creek subbasin actually lost forest cover in the very small area of the subbasin inside the UGA, and gained forest cover outside the UGA.

**Table 4. Forest cover (acres) in all of WRIA 8 by Tier, inside and outside the UGA.**

| Location | Tier | 1991 | 1996 | 2001 | 2006 |
|---|---|---|---|---|---|
| Urban (in UGA) | 1 | 9,340 | 8,619 | 7,890 | 7,425 |
| | 2 | 10,422 | 9,474 | 8,638 | 7,978 |
| | 3 | 32,955 | 31,289 | 29,707 | 28,648 |
| Rural (outside UGA) | 1 | 38,434 | 38,230 | 38,310 | 38,047 |
| | 2 | 83,433 | 85,313 | 85,844 | 85,816 |
| | 3 | 10,379 | 10,354 | 10,211 | 10,169 |

## Evergreen Forest

Tables C-3a and C-3b in Appendix C present forest area and percent of basin separated into the urban and rural areas. Table 5 presents forest conversion in each of the three time periods with a focus on evergreen forest. "Gain" includes conversion from any cover type to evergreen forest, and "loss" includes change from evergreen to any other cover type.

**Table 5. Acres of evergreen forest conversion in each of the three time change periods.**

| | Acres, Total forest (Evergreen) | | |
|---|---|---|---|
| | 1991-1996 | 1996-2001 | 2001-2006 |
| Loss* | -4970 (-2630) | -4937 (-2120) | -2627 (-767) |
| Gain* | 3284 (2172) | 2259 (1202) | 123 (123) |
| Net Change | -1686 (-458) | -2679 (-918) | -2504 (-644) |

* Loss or gain from any type of conversion, including other forest types; gain is mostly from scrub/shrub and grassland.

Table 6 presents evergreen forest loss and gain, with areas inside and outside the urban growth area boundaries displayed separately.

**Table 6. Change in evergreen forest cover (acres), inside vs. outside the UGA.**

| | 1991 - 1996 | 1996 - 2001 | 2001 - 2006 |
|---|---|---|---|
| Evergreen loss in UGA | -1713 | -1166 | -538 |
| Evergreen loss outside UGA | -917 | -954 | -229 |
| Evergreen loss in total area | -2630 | -2120 | -767 |
| Evergreen gain in UGA | 45 | 24 | 5 |
| Evergreen gain outside UGA | 2127 | 1178 | 118 |
| Evergreen gain in total area | 2172 | 1202 | 123 |
| Net change in UGA | -1667 | -1141 | -533 |
| Net change outside UGA | 1209 | 223 | -111 |
| Net change in total area | -458 | -918 | -644 |

### Forest Conversion

Table 7 presents the total acres of forest converted to developed area in each of the three change datasets (1991-1996, 1996-2001, and 2001-2006) summarized by UGA/non-UGA. Table C-5 in Appendix C presents the total acres of forest in WRIA 8 converted to developed area for each classification in each of the three change datasets.

**Table 7. Forest to developed acres conversion inside and outside the UGA, grouped by Tier.**

| Tier | Forest Conversion Class Name | 1991 - 1996 | 1996 - 2001 | 2001 - 2006 |
|---|---|---|---|---|
| 1 | Deciduous Forest to Developed Area, in UGA | 89.9 | 27.9 | 43.7 |
| | Evergreen Forest to Developed, in UGA | 403.5 | 255.1 | 71.4 |
| 39.1% | Mixed Forest to Developed, in UGA | 255.8 | 175.0 | 288.5 |
| of Tier 1 | Deciduous Forest to Developed Area, outside UGA | 39.7 | 7.6 | 3.1 |
| in UGA | Evergreen Forest to Developed, outside UGA | 163.1 | 113.5 | 6.4 |
| | Mixed Forest to Developed, outside UGA | 119.7 | 95.9 | 8.1 |
| 2 | Deciduous Forest to Developed Area, in UGA | 60.3 | 14.8 | 106.7 |
| | Evergreen Forest to Developed, in UGA | 471.4 | 311.6 | 231.3 |
| 24.1% | Mixed Forest to Developed, in UGA | 345.7 | 358.3 | 303.1 |
| of Tier 2 | Deciduous Forest to Developed Area, outside UGA | 20.4 | 12.8 | 17.0 |
| in UGA | Evergreen Forest to Developed, outside UGA | 141.1 | 153.4 | 31.1 |
| | Mixed Forest to Developed, outside UGA | 86.9 | 155.7 | 26.9 |
| 3 | Deciduous Forest to Developed Area, in UGA | 182.0 | 45.6 | 237.9 |
| | Evergreen Forest to Developed, in UGA | 741.1 | 390.9 | 206.1 |
| 89.6% | Mixed Forest to Developed, in UGA | 752.3 | 854.3 | 464.9 |
| of Tier 3 | Deciduous Forest to Developed Area, outside UGA | 2.6 | 2.7 | 0.6 |
| in UGA | Evergreen Forest to Developed, outside UGA | 14.7 | 38.1 | 0.7 |
| | Mixed Forest to Developed, outside UGA | 7.4 | 81.2 | 2.7 |

## 3.1.2 Development

### Developed Area

The total area and percent cover of developed area in each subbasin is presented in Table C-6 in Appendix C along with the rate of change (acres per year) for the entire time period (1991-2006). Tier 1 subbasins displayed a combined total of 31 percent developed area in 2006, an increase from 28 percent in 1991. North Fork Issaquah showed a higher gain in developed area across the study period than the other basins: in 1991, 26 percent of the basin was covered in developed area, and by 2006, 46 percent of the basin was in developed area. Tier 2 subbasins had a total of 23 percent developed area per basin in 2006, an increase from 20 percent in 1991. The greatest gain in percent developed in Tier 2 subbasins over the period under analysis was in the Lower North subbasin, which gained an average of 71.4 acres/year (approximately 11 percent of the subbasin). Tier 3 subbasins combined were 68 percent developed in 2006, an increase from 64 percent in 1991.

Table 8 summarizes the total area, by year, for each land classification used to calculate developed area.

**Table 8. Developed area (acres) by land class in all of WRIA 8, by UGA.**

| Tier | Developed Area Class Name | 1991 | 1996 | 2001 | 2006 |
|---|---|---|---|---|---|
| 1 | Bare Land, in UGA | 376.4 | 365.9 | 421.4 | 409.1 |
| | Developed Open Space, in UGA | 2279.3 | 2416.0 | 2516.4 | 2592.9 |
| | High Intensity Developed, in UGA | 4382.4 | 4430.4 | 4528.2 | 4632.6 |
| | Medium Intensity Developed, in UGA | 8635.3 | 9158.8 | 9327.2 | 9473.3 |
| 39.1% | Low Intensity Developed, in UGA | 8040.2 | 8328.3 | 8495.4 | 8959.6 |
| of Tier 1 | *Total, in UGA* | *23,713.6* | *24,699.4* | *25,288.6* | *26,067.5* |
| in UGA | Bare Land, outside UGA | 380.0 | 362.1 | 339.5 | 1015.0 |
| | Developed Open Space, outside UGA | 3375.1 | 4632.8 | 4832.8 | 4839.3 |
| | High Intensity Developed, outside UGA | 1135.8 | 1016.7 | 1053.6 | 1109.8 |
| | Medium Intensity Developed, outside UGA | 11194.6 | 13261.5 | 13681.8 | 13676.1 |
| | Low Intensity Developed, outside UGA | 6366.8 | 4514.1 | 4623.0 | 5096.0 |
| | *Total, outside UGA* | *22,452.3* | *23,787.2* | *24,530.7* | *25,736.2* |
| 2 | Bare Land, in UGA | 366.8 | 315.1 | 235.1 | 129.9 |
| | Developed Open Space, in UGA | 2789.4 | 2900.0 | 3084.0 | 2907.0 |
| | High Intensity Developed, in UGA | 2709.5 | 2818.7 | 2948.7 | 3164.1 |
| | Medium Intensity Developed, in UGA | 10344.5 | 10965.8 | 11268.1 | 11495.7 |
| 24.1% | Low Intensity Developed, in UGA | 6115.7 | 6522.0 | 6857.4 | 7789.1 |
| of Tier 2 | *Total, in UGA* | *22,325.9* | *23,521.6* | *24,393.3* | *25,485.8* |
| in UGA | Bare Land, outside UGA | 44.2 | 164.8 | 156.9 | 547.5 |
| | Developed Open Space, outside UGA | 2403.9 | 3254.3 | 3503.6 | 3306.6 |
| | High Intensity Developed, outside UGA | 1348.3 | 1219.1 | 1259.4 | 1280.0 |
| | Medium Intensity Developed, outside UGA | 10045.7 | 12237.4 | 12586.6 | 12588.3 |
| | Low Intensity Developed, outside UGA | 3438.3 | 1503.3 | 1629.7 | 1925.2 |
| | *Total, outside UGA* | *17,280.4* | *18,378.9* | *19,136.2* | *19,647.6* |
| 3 | Bare Land, in UGA | 415.3 | 243.2 | 81.6 | 100.7 |
| | Developed Open Space, in UGA | 7942.1 | 8563.9 | 8919.3 | 8790.5 |
| | High Intensity Developed, in UGA | 8077.5 | 7694.3 | 7760.8 | 7953.0 |
| | Medium Intensity Developed, in UGA | 45880.1 | 47875.3 | 48540.3 | 48637.8 |
| 89.6% | Low Intensity Developed, in UGA | 27910.3 | 28184.1 | 28723.1 | 29760.4 |
| of Tier 3 | *Total, in UGA* | *90,225.3* | *92,560.8* | *94,025.1* | *95,242.4* |
| in UGA | Bare Land, outside UGA | 68.4 | 50.0 | 24.1 | 289.0 |
| | Developed Open Space, outside UGA | 1507.5 | 1955.6 | 2059.9 | 2034.4 |
| | High Intensity Developed, outside UGA | 4808.0 | 4854.5 | 4849.6 | 4896.3 |
| | Medium Intensity Developed, outside UGA | 26652.5 | 27966.7 | 28878.9 | 28742.1 |
| | Low Intensity Developed, outside UGA | 9754.5 | 9552.1 | 9708.8 | 10284.6 |
| | *Total, outside UGA* | *42,790.9* | *44,378.9* | *45,521.3* | *46,246.4* |

In our analyses, bare land is included in the calculations for "developed area"; therefore, changes from bare land to some other type of developed area would be missed when looking at forest-to-

developed area data. These change classes likely indicate areas that were cleared previously and developed (Table 9). Of the 338.9 acres classified as bare land converted to some form of development in the most recent time frame of 2001 to 2006, the bulk of this development (82 percent) was in two subbasins: 147 acres in Evans and 131 acres in North Fork Issaquah. Nearly all of this development was inside the Urban Growth Area boundary (333.5 of the 338.9 acres).

**Table 9. Conversion from bare land to development (acres) in all of WRIA 8.**

| Change Class | 1991-1996 | 1996-2001 | 2001-2006 |
|---|---|---|---|
| Bare Land to Developed Open Space | 29.10 | 41.89 | 14.11 |
| Bare Land to High Intensity Developed | 2.20 | 98.55 | 80.92 |
| Bare Land to Medium Intensity Developed | 85.99 | 191.37 | 157.42 |
| Bare Land to Low Intensity Developed | 326.75 | 127.66 | 86.43 |
| Total (acres) | 444.0 | 459.5 | 338.9 |

Of the non-forest, non-bare-land cover classes, those cover classes showing the most conversion to developed area are grassland (728 acres) and scrub-shrub (241 acres) areas. These converted areas account for 1,292 acres in the most recent time frame.

### Impervious Area

The total area and percent of impervious area in each subbasin is presented in Table C-7 in Appendix C. Within Tier 1 subbasins, North Fork Issaquah showed the highest overall rate of change: it added an average of 21 acres of impervious area per year. Three other Tier 1 subbasins added more than 10 acres per year: Upper Sammamish Valley (17), Lower Bear (16), and Lower Sammamish Valley (11). In Tier 2, the Lower North subbasin added the most impervious area per year (56 acres), followed by Upper North (32), Evans (28), and Little Bear (20). In 2006, all but two Tier 3 subbasins had over 10 percent impervious area.

Table 10 summarizes the impervious area in each of the three tiers, both inside and outside the UGA.

**Table 10. Impervious area (acres) in all of WRIA 8 by Tier, inside and outside the UGA.**

| Location | Tier | 1991 | 1996 | 2001 | 2006 |
|---|---|---|---|---|---|
| Urban (in UGA) | 1 | 11,626 | 12,110 | 12,541 | 13,057 |
| | 2 | 9,326 | 9,917 | 10,663 | 11,497 |
| | 3 | 38,977 | 40,020 | 41,058 | 42,153 |
| Rural (outside UGA) | 1 | 2,261 | 2,390 | 2,434 | 2,488 |
| | 2 | 1,487 | 1,606 | 1,691 | 1,757 |
| | 3 | 493 | 502 | 536 | 547 |

## 3.2 Riparian Area

All land cover classes within each 165-foot-buffer grid-square reach were tabulated for each of the eight subbasins in the riparian study for 2005 and 2009 (Table 11). Three of four Tier 1 subbasins showed a slight (less than 1 percent) increase in forest area; only Lower Bear showed a

decrease (3.9 percent). However, all four Tier 1 subbasins examined in the riparian study showed an increase in impervious surface in the riparian buffer. Two of the four Tier 2 subbasins had an increase in forest from 2005 to 2009, and all four had an increase in impervious area.

**Table 11. Percent of sampled riparian buffer in each of the five land cover classes, 2005 and 2009. Percentages are for the area within approximately 165 feet on either side of the stream.**

| Tier | Subbasin | # reaches sampled | % forest | | % shrub | | % impervious | | % water | | % other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2005 | 2009 | 2005 | 2009 | 2005 | 2009 | 2005 | 2009 | 2005 | 2009 |
| 1 | Lower Bear | 10 | 33.7 | 29.8 | 28.5 | 25.1 | 14.0 | 16.9 | 1.7 | 2.4 | 22.1 | 25.7 |
| | East Fork Issaquah | 5 | 44.8 | 45.2 | 23.3 | 22.4 | 18.9 | 19.2 | 0.0 | 0.4 | 13.0 | 12.8 |
| | North Fork Issaquah | 1 | 12.3 | 12.6 | 28.6 | 23.5 | 38.2 | 39.2 | 0.2 | 0.2 | 20.8 | 24.5 |
| | Upper Bear | 8 | 51.7 | 52.4 | 30.6 | 25.4 | 4.6 | 4.9 | 2.0 | 4.2 | 11.2 | 13.1 |
| 2 | Cedar North Rural | 3 | 43.2 | 45.0 | 25.8 | 19.4 | 14.6 | 14.8 | 0.5 | 1.5 | 15.9 | 19.3 |
| | Evans | 8 | 48.5 | 45.8 | 19.8 | 17.5 | 5.4 | 6.0 | 0.8 | 1.3 | 25.7 | 29.5 |
| | Lower North | 10 | 31.3 | 32.3 | 26.9 | 25.5 | 19.7 | 21.2 | 0.9 | 2.3 | 21.2 | 18.7 |
| | Upper North | 9 | 56.7 | 54.8 | 11.0 | 11.3 | 11.5 | 12.0 | 0.7 | 3.2 | 20.0 | 18.7 |

Land cover class data were summed for Tier 1 and Tier 2 reaches and grouped by whether the area was inside or outside the Urban Growth Area (UGA) (Table 12). When grouped this way, forest is decreasing in all groups, and impervious is increasing in all groups.

**Table 12. Percent of area within an approximately 165-foot buffer in each of the five land cover classes in 2005 and 2009, grouped by tier.**

| | UGA | Year | Forest/ Tree | Shrub | Impervious | Water | Other | Total acres in area |
|---|---|---|---|---|---|---|---|---|
| Tier 1 | Inside | 2005 | 29.1 | 27.1 | 20.4 | 1.4 | 22.0 | 91.2 |
| | | 2009 | 25.1 | 23.7 | 24.5 | 2.1 | 24.7 | 91.2 |
| | Outside | 2005 | 45.4 | 28.5 | 10.2 | 1.3 | 14.5 | 248.4 |
| | | 2009 | 45.1 | 24.9 | 10.8 | 2.6 | 16.7 | 248.4 |
| Tier 2 | Inside | 2005 | 43.4 | 19.5 | 15.7 | 0.8 | 20.6 | 272.9 |
| | | 2009 | 42.9 | 19.0 | 16.7 | 2.7 | 18.7 | 273.1 |
| | Outside | 2005 | 46.9 | 21.2 | 8.0 | 0.7 | 23.1 | 156.0 |
| | | 2009 | 45.7 | 17.6 | 8.5 | 1.4 | 26.8 | 156.0 |

Regulatory buffers for each jurisdiction present within the sampled area were determined (Table 13), then only those grid squares falling fully or partially within the regulatory buffer were included in subsequent analysis. Figure D1(a-h) in Appendix D graphically depicts the information in Table 13.

**Table 13. Acres within agency-appropriate regulatory buffers in each of the five land cover classes in 2005 and 2009, grouped by jurisdiction within each subbasin.**

| | | | forest/tree | | shrub | | impervious | | water | | other | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Subbasin** | **Jurisdiction** | **Buffer** | 2005 | 2009 | 2005 | 2009 | 2005 | 2009 | 2005 | 2009 | 2005 | 2009 |
| Lower Bear | King County rural | 165 | 23.4 | 21.5 | 20.3 | 17.6 | 6.9 | 7.6 | 1.1 | 1.5 | 14.3 | 17.7 |
| | King County UGA | 115 | 3.4 | 3.3 | 1.9 | 1.6 | 0.9 | 1.0 | - | - | 4.3 | 5.0 |
| | City of Redmond | 150 | 19.6 | 16.6 | 17.6 | 15.7 | 9.3 | 12.7 | 1.2 | 1.8 | 9.6 | 10.6 |
| East Fork Issaquah | King County rural | 165 | 31.8 | 32.0 | 16.5 | 15.9 | 13.4 | 13.6 | 0.0 | 0.2 | 9.2 | 9.1 |
| N. Fork Issaquah | City of Issaquah | 100 | 1.4 | 1.6 | 3.2 | 2.4 | 2.7 | 2.8 | 0.02 | 0.02 | 2.2 | 2.6 |
| Upper Bear | City of Redmond (Watershed Preserve) | 150 | 3.0 | 3.3 | 2.1 | 1.4 | - | - | 0.8 | 1.0 | - | 0.1 |
| | King County rural | 165 | 54.2 | 54.6 | 31.8 | 26.7 | 5.1 | 5.4 | 1.4 | 3.7 | 12.5 | 14.5 |
| Cedar North Rural | King County rural | 165 | 18.8 | 19.6 | 11.2 | 8.4 | 6.4 | 6.4 | 0.2 | 0.7 | 6.9 | 8.4 |
| Evans | City of Redmond | 150 | 0.6 | 0.4 | 0.5 | 0.6 | - | - | - | - | 0.1 | 0.1 |
| | King County rural | 165 | 54.5 | 51.8 | 22.0 | 19.2 | 6.2 | 6.8 | 0.9 | 1.5 | 29.2 | 33.5 |
| Lower North | City of Bothell | 100 | 6.4 | 7.9 | 15.0 | 13.5 | 9.6 | 10.5 | 0.6 | 1.3 | 9.7 | 8.2 |
| | Snohomish County | 150 | 33.0 | 32.5 | 18.8 | 18.5 | 9.0 | 9.7 | 0.5 | 1.6 | 11.6 | 10.5 |
| Upper North | SnoCo, inside UGA | 150 | 6.4 | 5.3 | 2.0 | 1.7 | 3.0 | 3.4 | - | 0.1 | 1.9 | 2.8 |
| | City of Everett | 100 | 10.1 | 10.3 | 2.7 | 2.3 | 3.2 | 3.2 | - | - | 2.4 | 2.5 |
| | City of Mill Creek | 75 | 28.0 | 26.3 | 5.0 | 6.6 | 1.0 | 1.2 | 0.8 | 2.6 | 8.9 | 7.1 |

# 4.0. ANALYSIS AND DISCUSSION

## 4.1 Basin-wide Analyses

The questions that are examined in this report, including how much change has occurred in forest cover and in developed area, were instigated in order to develop a greater understanding of trends in forest protection in WRIA 8, especially in areas considered important for salmon recovery. In this section, we consider forest protection from two perspectives. First, we follow up on analyses performed as part of the Chinook conservation planning process and focus on those basins identified by Leonetti et al. (2005) to be most at-risk for land cover changes detrimental to salmon conservation. The remaining sections discuss other aspects of land cover change in the watershed.

### 4.1.1 "At-Risk" Basins

During the WRIA 8 Chinook conservation planning process, Leonetti et al. (2005) developed a watershed evaluation framework that identified subbasins likely to be most at risk for land cover change detrimental to salmon recovery (Table 14). In most cases their predictions were based on the projected change in subbasin impervious area and forested land cover, as well as the estimated change in riparian forested land cover[9]. In Table 14 we consider those subbasins in the context of the rate of change (ROC) in acres per year for some of the parameters investigated for this study.

*Developed Area.* Table C-6 in Appendix C shows the ROC in total developed area over the entire period for which C-CAP data are available (1991-2006). However, it is useful to examine the rate of change in the most recent five year interval (2001-2006) to assess the condition of those identified most at-risk basins. The column numbered "1" in Table 14 below presents ROC data for both the 2001-2006 timeframe and the entire 1991-2006 timeframe. In most instances, the ROC in column 1 is greater for the entire 1991-2006 period than it is for the most recent 2001-2006 period. Where the ROC for the most recent period is higher than the longer-term ROC (indicating an increase in rate of development in the most recent time period), those figures are in red text. Those basins include Cedar Main Urban, North Fork Issaquah, and East Fork Issaquah in Tier 1, and Rock, Evans, and Lower North Creek in Tier 2.

*Impervious Area.* Column 2 displays ROC for the strictly impervious dataset (see Section 3.1.2). As with Column 1, Column 2 presents ROC data for the 2001-2006 timeframe as well as the entire 1991-2006 timeframe. Where the ROC for the most recent time frame is higher than the longer-term ROC for impervious area, those figures are in red text.

*Forest Cover.* Column 3 displays the percent change (%Δ) for forest cover. These %Δ values were used to determine what basins to examine in greater depth via the riparian study (see Section 2.3). Note the values in column 3 represent the 2001-2006 period. The %Δ values were divided into groups by looking at natural breaks in the overall distribution of the data. Values

[9] Some subbasins (Cedar Main Urban, Cedar North Rural, Lower Bear, Evans, Little Bear, and Upper North and Lower North Creeks) were identified as requiring restoration of degraded areas as well as protection of intact areas.

between 0 and -1.7 (or positive values) were labeled as low, values from -1.8 to -3.0 were labeled moderate, and any loss greater than -3.0 was labeled high. All Tier 1 and Tier 2 basins with 1.8 %Δ or greater (therefore, those subbasins labeled moderate and high for percent loss of forest area) were examined in the riparian study,[10] because those were the basins that had lost the greatest proportion of their forested areas in the study period and therefore might be most at risk of degradation via continued forest loss. Red text in column 3 denotes subbasins labeled most at risk of degradation via continued forest loss.

*Riparian Area.* Data in columns 4 and 5 are from the riparian study, which used aerial photos from 2005 and 2009. Specifically, these numbers are for the 165-ft riparian buffer. Percent change is shown for both impervious area (column 4) and forest/tree area (column 5). Impervious area increased overall in all sampled basins, whereas forest area increased in some basins and decreased in others. Any loss in forest is shown in red text in column 5. Note that some jurisdictions have smaller regulated buffers than 165 feet; see Section 4.2 below for additional discussion.

Although this study and Leonetti et al. (2005) relied on different methods and cannot be compared directly, our study appears to confirm that a number of subbasins they identified are continuing on a trajectory that could result in future reclassification should a similar watershed characterization be conducted – that is, some areas classified as Tier 1 or Tier 2 might warrant downgrading to Tier 2 and Tier 3, respectively.

[10] Upper Issaquah had a %Δ of 2.7 but was not examined in the riparian study for reasons described in the Methods section.

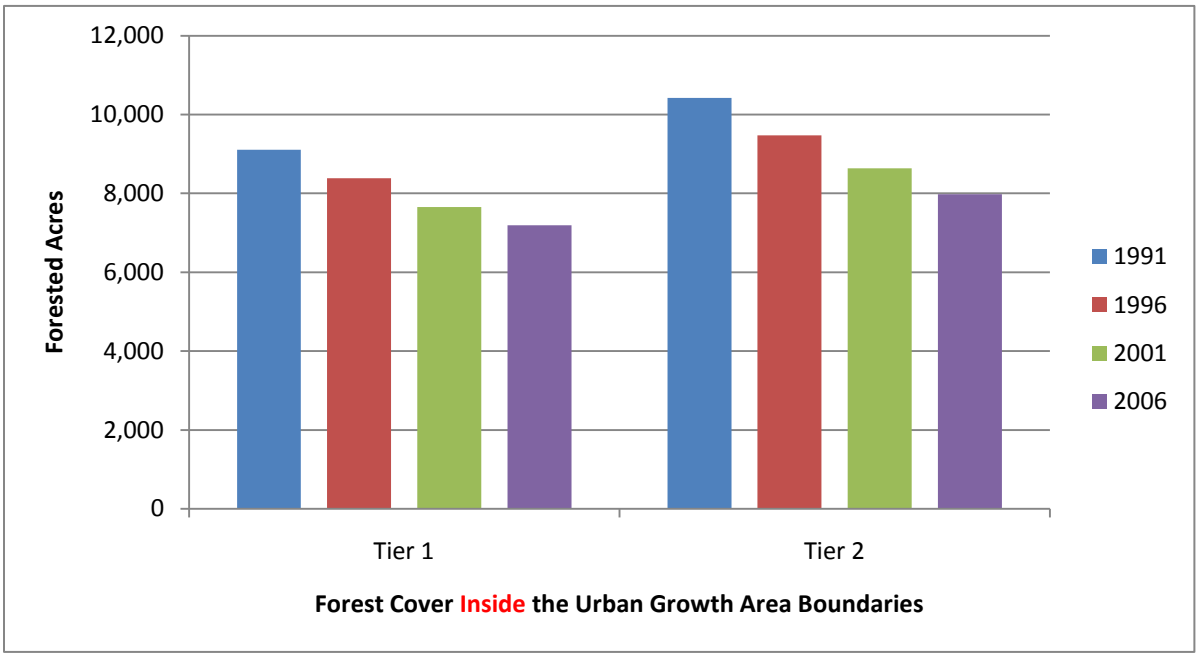
**Table 14. Comparison of forest and development data for basins identified previously as most at-risk for degradation.** Note that these figures represent the entire basin and are not divided into urban and rural areas. Red text in columns 1 and 2 denotes a higher rate of change (ROC) for most recent period compared to entire period; red text in column 3 denotes subbasins labeled most at risk of degradation via continued forest loss; and red text in column 5 denotes loss of forest cover within the riparian area of 165 ft, regardless of regulatory context.

| Tier | Subbasins identified as most at-risk of degradation (Leonetti et al. 2005) | Based on C-CAP data | | | Riparian study* | |
|---|---|---|---|---|---|---|
| | | 1. Developed area ROC, acres/year, 2001-2006 (1991-2006) | 2. Impervious ROC, acres/year, 2001-2006 (1991-2006) | 3. Forest %Δ, 2001-2006 | 4. Impervious area %Δ, 2005-2009 | 5. Forest/Tree area %Δ, 2005-2009 |
| 1 | Upper Bear | 16 (23.2) | 8.0 (7.4) | -1.87 | 6.80 | 1.42 |
| 1 | Cottage Lake | 0.5 (14.8) | 1.7 (5.6) | -0.43 | NA | NA |
| 1 | Lower Bear | 15.5 (19.7) | 15.7 (15.7) | -2.23 | 21.04 | -11.51 |
| 1 | Cedar Main Urban | 58.8 (32.1) | 11.5 (9.4) | -0.78 | NA | NA |
| 1 | Cedar Main Rural | 11.6 (18.3) | 6.9 (7.8) | -0.33 | NA | NA |
| 1 | Middle Issaquah | 6 (4.6) | 0.3 (0.9) | -0.11 | NA | NA |
| 1 | North Fork Issaquah | 63.7 (39.5) | 44.6 (21.2) | -12.53 | 2.64 | 2.74 |
| 1 | East Fork Issaquah | 31.9 (16.2) | 12.0 (4.2) | -2.02 | 1.85 | 0.78 |
| 1 | Lower Issaquah | 2.1 (11.1) | 2.8 (7.8) | -0.15 | NA | NA |
| 2 | Rock Creek | 51.4 (41.0) | 7.5 (9.6) | -1.13 | NA | NA |
| 2 | Evans Creek | 75 (57.2) | 42.8 (28.5) | -3.30 | 10.4 | -5.41 |
| 2 | Little Bear Creek | 11.1 (45.5) | 10.3 (20.0) | -1.23 | NA | NA |
| 2 | Cedar North Rural | 8.9 (10.3) | 7.9 (3.5) | -1.81 | 1.17 | 4.07 |
| 2 | Upper North Creek | 28.6 (42) | 31.1 (32.1) | -5.38 | 4.69 | -3.25 |
| 2 | Lower North Creek | 97 (71.4) | 77.3 (56.5) | -12.11 | 7.20 | 3.10 |
| 3 | May Creek | 18.1 (30.9) | 12.2 (14.4) | -1.61 | NA | NA |
| 3 | Coal Creek | 11.4 (21.3) | 2.1 (6.8) | -3.45 | NA | NA |
| 3 | Peterson Creek | 7.8 (8.1) | 4.6 (4.4) | -1.97 | NA | NA |
| 3 | Upper Swamp Creek | 40.3 (45.5) | 40.1 (32.8) | -10.55 | NA | NA |
| 3 | Lower Swamp Creek | 26.3 (21.1) | 21.6 (15.5) | -7.66 | NA | NA |
| 3 | McAleer Creek | 0.4 (4.7) | 3.7 (5.8) | -0.35 | NA | NA |
| 3 | East Lake Samm. | 41.2 (73.3) | 20.1 (37.4) | -4.40 | NA | NA |

### 4.1.2 Forest Cover

One of the primary questions asked in this analysis is how much forest is being converted to development. To find the answer, one must examine change in forest cover as well as change in development. Further, change may occur both temporally and spatially. Therefore, not only must forest cover be compared across the years of the study, but one also must look at where within the basins forest is being lost or gained. A logical place to start is to divide subbasins based on the Urban Growth Boundary. Additionally, the information can be sorted based on Tiers. Overall, forest cover in Tier 1 and Tier 2 areas inside the UGA declined 21 percent and 23 percent, respectively, between 1991 and 2006 (Figure 6).

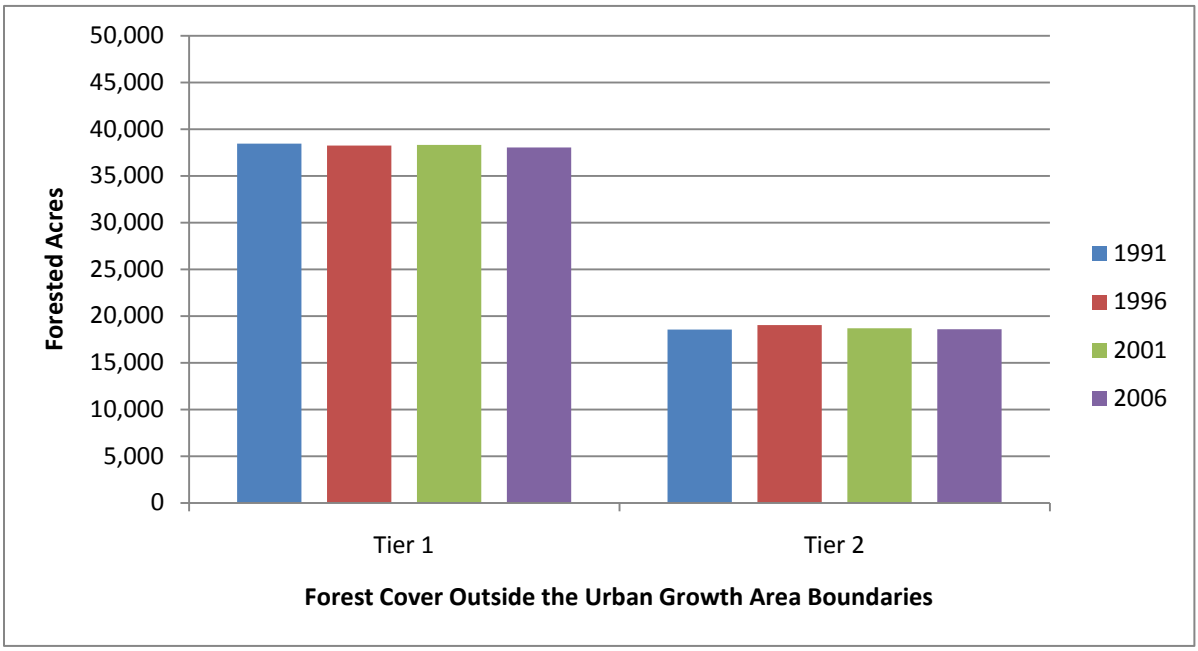
**Figure 6. Forest cover change inside the UGA based on C-CAP data.**




Approximately 25 percent (over 110,000 acres) of the land area in WRIA 8 lies in public ownership. Outside the UGA, large tracts of protected forest include the Cedar River Municipal Watershed (over 80,000 acres), Cougar Mountain Regional Park (over 3,000 acres), and Squak Mountain State Park (about 2,000 acres). If a protected area as large as the Cedar River Municipal Watershed (comprising about 72 percent of all Tier 2 forest cover in WRIA 8) were included in our analyses, its inclusion could mask losses in unprotected areas. Therefore, Figure 7 shows forest cover in each study year for areas outside the UGA with land inside the Cedar River Municipal Watershed (i.e., the Upper Cedar subbasin) removed from the analysis. Even with the exclusion of this substantial area, change over the period from 1991 to 2006 was too small to reliably measure (-1 percent and +2.9 percent in Tier 1 and Tier 2 areas, respectively). In

other words, in contrast to forest cover inside the UGA, outside the UGA forest cover is not detectably declining or increasing when analyzed at this spatial scale.[11]

**Figure 7. Forest cover change outside the UGA based on C-CAP data. (Upper Cedar subbasin removed from Tier 2 data.)**

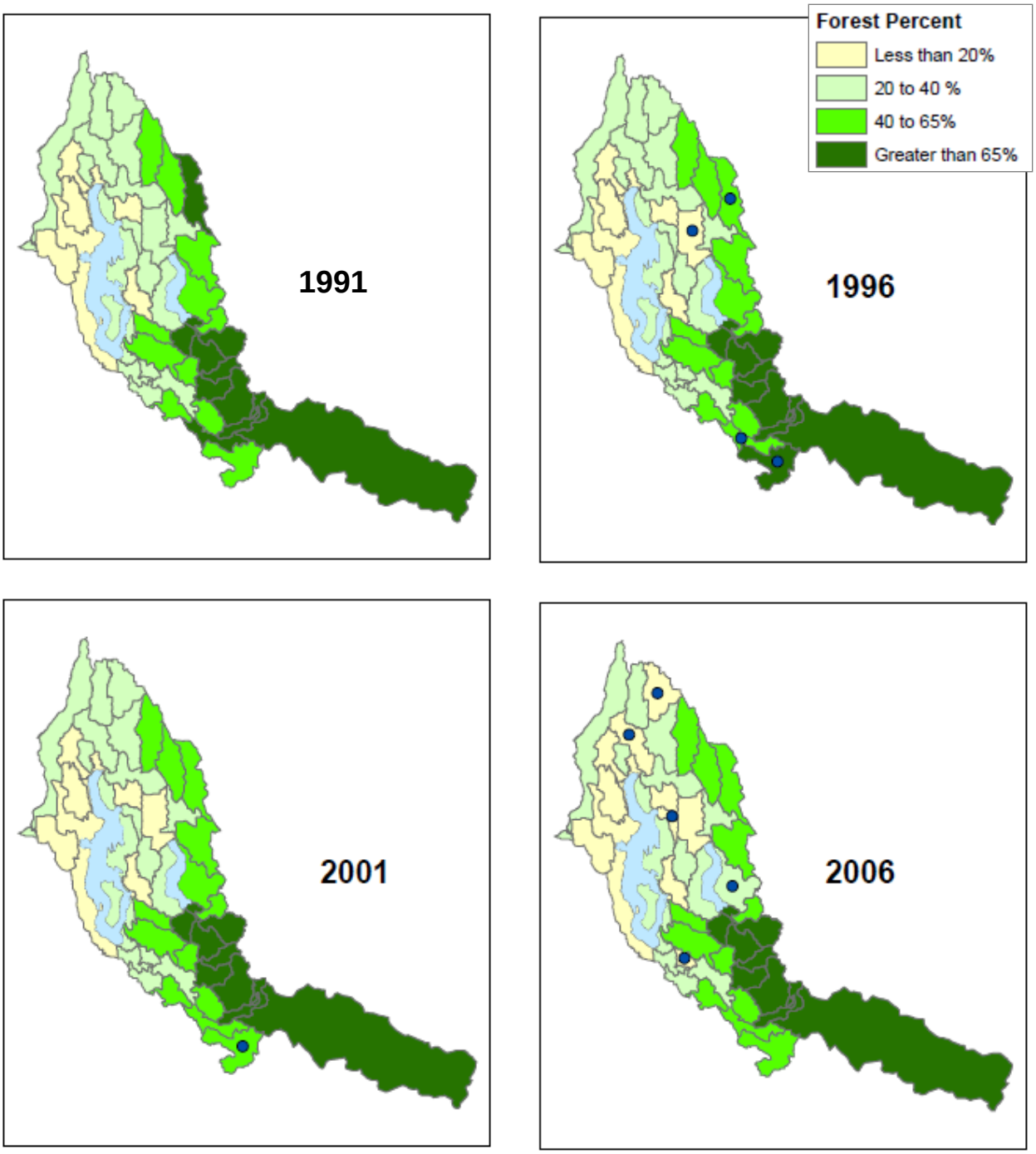



Leonetti et al. (2005) mapped percent forest cover in three categories (less than 20 percent, 20-40 percent, and greater than 40 percent). Those categories were based on natural break-points in their data. In order to attempt to include an ecological indicator into a similar mapping exercise, we added a break point at 65 percent, which is frequently used as a threshold below which degraded stream conditions within the watershed are expected to occur (Booth et al. 2002). Percent of total forest acreage of each subbasin for each of the four data years was mapped based on the data in Table C-1 in Appendix C generally following the break points used in Leonetti et al. (2005) with the addition of a break point at 65 percent. The results of these calculations, presented in Figure 8, show a change in category in the 2001-2006 time period in five subbasins (Upper North, Lower Swamp, Forbes, East Lake Sammamish, and Cedar North Urban). East Lake Sammamish went from 40-65 percent forest to the 20-40 percent category. The other four subbasins went from the 20-40 percent forest category to less than 20 percent. These maps illustrate in a very broad fashion where change in total forest area has occurred, but it does not examine the type of forest lost or conversion that is occurring.

[11] Given the basin-wide spatial scale used in this portion of the analysis, losses in forest cover in one area may be masked by offsetting gains in another area.

Overall, the most recent period (2001-2006) saw a smaller change in forest cover compared to earlier periods (see Table C-2, Appendix C). This decline in the amount of change may result from a number of factors, including stronger protective measures, a declining relative amount of forest cover to lose (the rate of forest conversion declines as an area approaches buildout), or a weaker economic climate. The East Fork Issaquah and Lower North subbasins were two exceptions to this trend, as these areas saw increases in percent change in the latest period. As in most areas in the watershed, the majority of forest cover loss in these two subbasins during this period occurred where land conversion is directed – inside the UGA boundaries.

**Figure 8. Percent of forest per basin.** Black dots within basins indicate those basins that changed categories from the previous data year. See text for explanation of categories.




## Evergreen Forest

Generally speaking, mature evergreen forest is indicative of conditions (hydrologic and otherwise) prior to European settlement in the Puget Sound region (e.g., Kruckeberg 1991; Collins et al. 2003). There are exceptions to this general statement, as many river flood plains in the Puget Sound lowlands also included high proportions of hardwoods (Collins et al. 2003).

However, in general, coniferous forests dominated the Puget Sound lowlands before western settlement, and even in flood plains, conifers provided the majority of biomass (Collins et al. 2003).

Given the ecological importance of mature evergreen forest cover, retaining (or restoring) it is considered to be one of the most protective actions that can be taken in WRIA 8 to help restore salmon populations. If forest cover is being converted from mature evergreen forest to deciduous forest, this change could be a significant indicator of changing watershed condition that would be missed if we lumped all forest classes together. So in order to not miss this potentially significant indicator, we extracted evergreen data to examine separately (Table C-4, Appendix C). Note that although C-CAP does not differentiate between age classes of evergreen forest, it may still be useful to have a greater understanding of gains and losses of evergreen forest in WRIA 8.

Outside the UGA, two Tier 1 subbasins showed an increase in evergreen forest acres/year (1991 - 2006): East Fork Issaquah (1.7 acres/year) and Lower Issaquah (0.7 acres/year). All other Tier 1 subbasins showed a loss of evergreen forest acres per year, with Upper Bear showing the greatest loss at 9.5 acres/year. All Tier 2 subbasins outside the UGA showed a loss of evergreen forest, with the exception of the Upper Cedar, which is almost entirely protected from logging; the Upper Cedar gained over 2,200 acres of evergreen forest across the study period as previously logged-over and replanted stands matured.

The results of the analysis show there has been a declining net gain of evergreen forest outside the UGA with the most recent period showing a net loss in overall evergreen forest cover for the first time (refer to Table 6 in Results section). A very large percentage of the net gain in all periods was from the Upper Cedar subbasin (which comprises the Cedar River Municipal Watershed). Of the 2127 acres in evergreen forest gain in the first period, 1589 acres were from the Upper Cedar; in the second period, 832 of the 1178 acres of evergreen forest gain were from the Upper Cedar (Table 15). In 2006, 75.1 percent of the Upper Cedar subbasin was classified as evergreen forest. Gains in the Upper Cedar are therefore masking the real story, which is loss of evergreen forest cover throughout the watershed.

**Table 15. Change in acres of evergreen forest, showing area outside the UGA, including the Upper Cedar Basin, and total area (modified from Table 6).**

| Type of Change | Location | 1991 - 1996 | 1996 - 2001 | 2001 - 2006 |
|---|---|---|---|---|
| Evergreen loss | Outside UGA | -917 | -954 | -229 |
| | Upper Cedar | -210 | -27 | -5 |
| | Total area | -2630 | -2120 | -767 |
| Evergreen gain | Outside UGA | 2127 | 1178 | 118 |
| | Upper Cedar | 1589 | 832 | 94 |
| | Total area | 2172 | 1202 | 123 |
| Net change | Outside UGA | 1209 | 223 | -111 |
| | Upper Cedar | 1379 | 805 | 90 |
| | Total area | -458 | -918 | -644 |

## Forest Conversion

We use the change data to estimate how much area of any given land cover class underwent conversion to another class between photo years. These three datasets (1991-1996, 1996-2001, and 2001-2006) show one facet of how the landscape evolved from one time period to the next.

The total amount of conversion from one land cover class to another was highest in the first time interval (1991-1996), with 9.6 percent of the subbasins changing from one land-cover type to another (Table 16). The lowest total change was in the most recent time interval (2001-2006), with 7.9 percent of the basin changing cover class. The cause for this decrease in the rate of change is unknown, but could include economic cycles, more protective land use and zoning rules, or other factors.

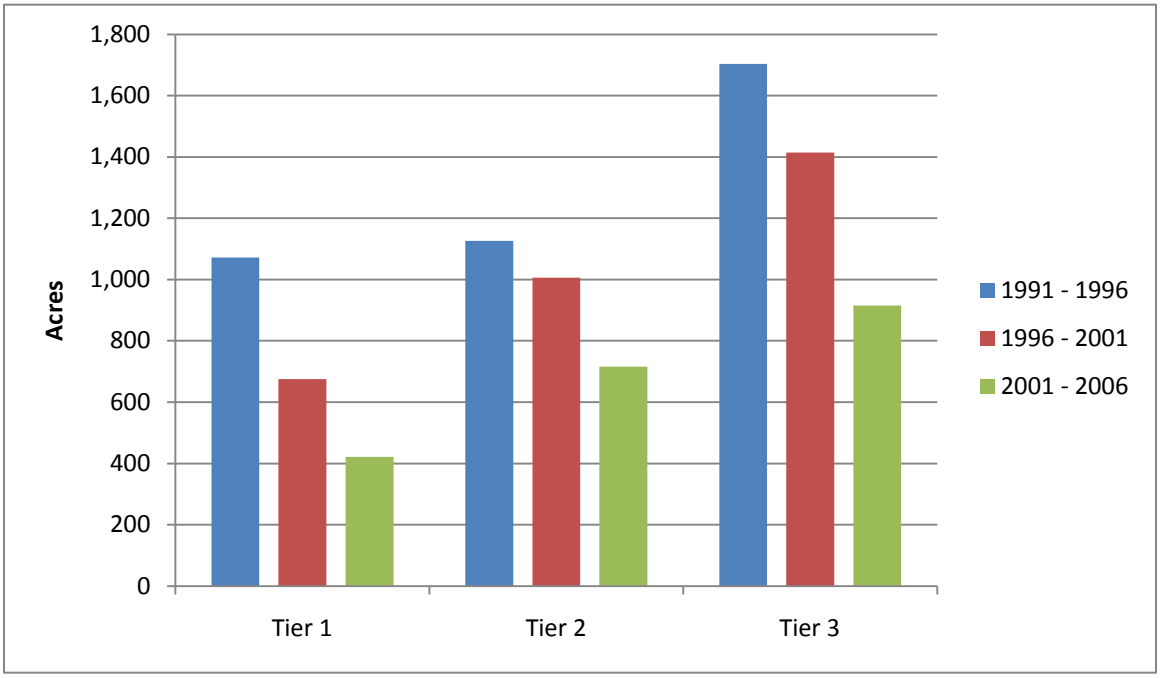
**Table 16. Summary of forest and developed area conversion in acres across WRIA 8 in each of the three time periods.**

| | 1991-1996 | 1996-2001 | 2001-2006 |
|---|---|---|---|
| **Total amount of area in dataset** | 388,285 | 388,285 | 388,285 |
| **Total area converted from any cover class to any other** | 37,398 (9.6%) | 32,687 (8.4%) | 30,828 (7.9%) |
| **Total forest converted to any other class** | 4,865 (1.3%) | 4,823 (1.2%) | 2,624 (0.7%) |
| **Any class converted to developed area** | 5,308 (1.4%) | 3,817 (1.0%) | 3,344 (0.9%) |
| **Total forest converted to developed area** | 3,901 (1.0%) | 3,096 (0.8%) | 2,052 (0.5%) |

Change data may be used to determine how much forest was converted to developed area within a given time period (e.g., 2001-2006). We cannot assume a single, direct transition of coniferous forest to development will always be the case within a single dataset, because development often does not occur that rapidly. A transition sequence might go from coniferous forest, for example, to shrub, to development, and in this instance the forest-to-developed-area transition would not be detected. As an example, Tier 1 basins lost 726 forest acres from 2001 to 2006, but only 421 acres were converted to development within that period. Therefore, the forest-to-developed-area analysis should be considered a subset of forest areas transitioning to development.

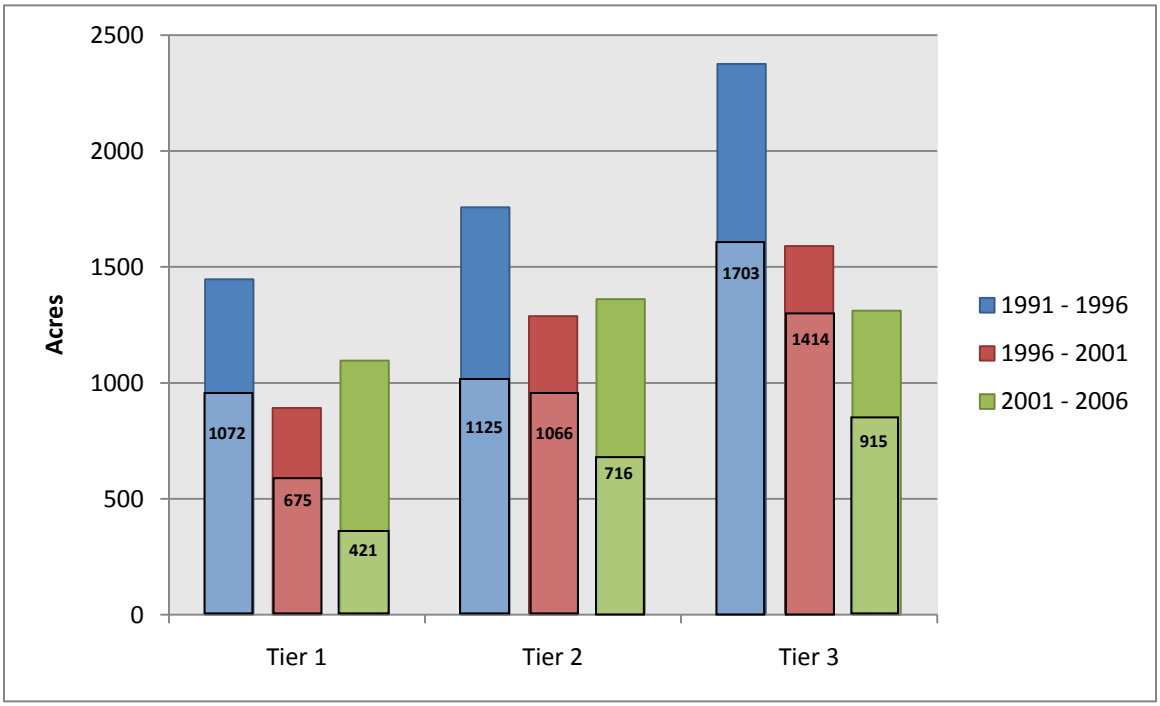
Figure 9 graphically depicts the change data presented in Table C-5 in Appendix C. The figure illustrates that the amount of change from forest to developed area decreased overall in all Tiers in each of the three periods (1991-1996, 1996-2001, and 2001-2006). Conversion from forest to developed area is lowest in any given period in Tier 1 and greatest in Tier 3.

**Figure 9. Forest to developed area by Tier, based on C-CAP change data presented in Table 4.**




Whereas Figure 9 shows overall trends in loss of forest to developed area, Figure 10 combines total gain in developed area with forest lost to developed area to show how much gain in development was from forested areas.

**Figure 10. Acres of gain in developed area, by Tier, based on C-CAP data. Bar inlays show acres of forest converted to developed area.**



### 4.1.3 Development

In order to better understand the information on development and impervious areas, it is useful to consider the total area comprised by each Tier, as well as the fraction of each Tier inside the UGA (Table 17). Tiers 2 and 3 are close to the same size in total area, but Tier 3 is almost 90 percent within the UGA (over 129,000 acres). The amount of acreage of Tiers 1 and 2 within the UGA are quite similar at approximately 36,000 to 37,000 acres. The area of Tier 2 outside the UGA is heavily skewed by the Upper Cedar subbasin, which accounts for over 82,000 acres (55 percent of total area and approximately 72 percent of forested area) in Tier 2.

**Table 17. Acreage per Tier and in the UGA.**

| Tier | total area | percentage of basins in UGA | acreage of tier in UGA |
|---|---|---|---|
| 1 | 94,570 | 39.1 | 36,977 |
| 2 | 149,062* | 24.1 | 35,924 |
| 3 | 144,653 | 89.6 | 129,609 |

*Tier 2 total acreage includes the Upper Cedar subbasin, which accounts for 82,078 acres, or 55% of Tier 2 area.

#### Developed Area

Five land cover classes comprise "developed area" (Figure 11). This figure illustrates that in all three tiers (for 2006), there is more high- and medium- intensity developed land cover inside the UGA than outside, and that more acreage of low-intensity developed land cover exists outside the UGA in Tiers 1 and 2. These differences are masked when all five land classes are lumped together.

Within the Tier 1 subbasins, development appears to be increasing most rapidly in the North Fork Issaquah subbasin, which had an average increase in developed area of 39.5 acres/year (Table C-6, Appendix C). This change equated to 29 percent of the basin being in developed area in 1991 and 46 percent of the basin in developed area by 2006. For comparison, the three basins showing the next highest increase in developed area are Lower Bear, Cedar Main Rural, and Cedar Main Urban (0.38, 0.37, and 0.36 percent per year, respectively). Except for the Lake Union subbasin, which remained at 87 percent developed area throughout the study period, the least amount of increase in developed area in Tier 1 subbasins was in the Fifteenmile subbasin (with 0.63 acres/year, or 0.02 percent of the basin per year). Middle Issaquah and Upper Issaquah were the next lowest, both with approximately 5 acres/year increases in developed area.

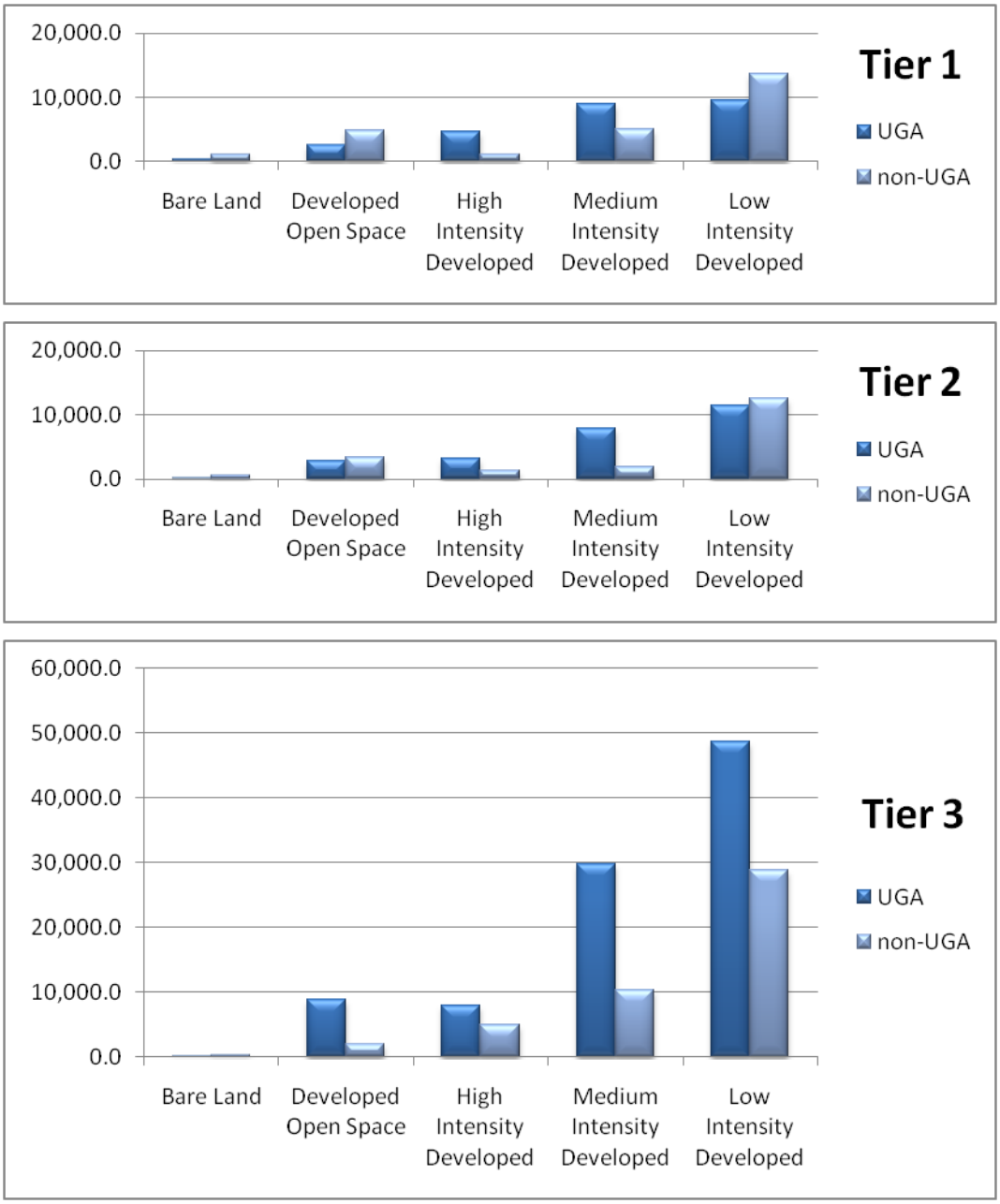
Within Tier 2, no subbasins showed an average increase in developed area of greater than 1 percent per year. However, some of the basins are larger than others, and despite the relatively low change in percent, five subbasins showed an average of over 40 acres per year in increased developed area: Lower North (71 acres/year), Evans (57 acres/year), Little Bear (46 acres/year), Upper North (42 acres/year), and Rock (41 acres/year). On the other hand, Walsh Lake subbasin, which is only at 5 percent developed area, showed an increase of less than 1 acre per year (0.2 acres/year).

Tier 3 subbasins are generally the most developed in WRIA 8: almost 90 percent of the area of Tier 3 is within the UGA. These subbasins range from 20 to 90 percent developed area, with an average of 66 percent in developed area in 2006, and an average increase in developed area of 17

acres/year. In 2006, East Lake Sammamish was at 52 percent developed area in 2006 (up from 41 percent in 1991), and increased at an average rate of 73 acres/year – the greatest increase in any Tier 3 subbasin.

For specifics on each subbasin in WRIA 8, refer to Table C-6 in Appendix C.

**Figure 11. Developed area categories by Tier for study year 2006, based on C-CAP data.**




## Impervious Area

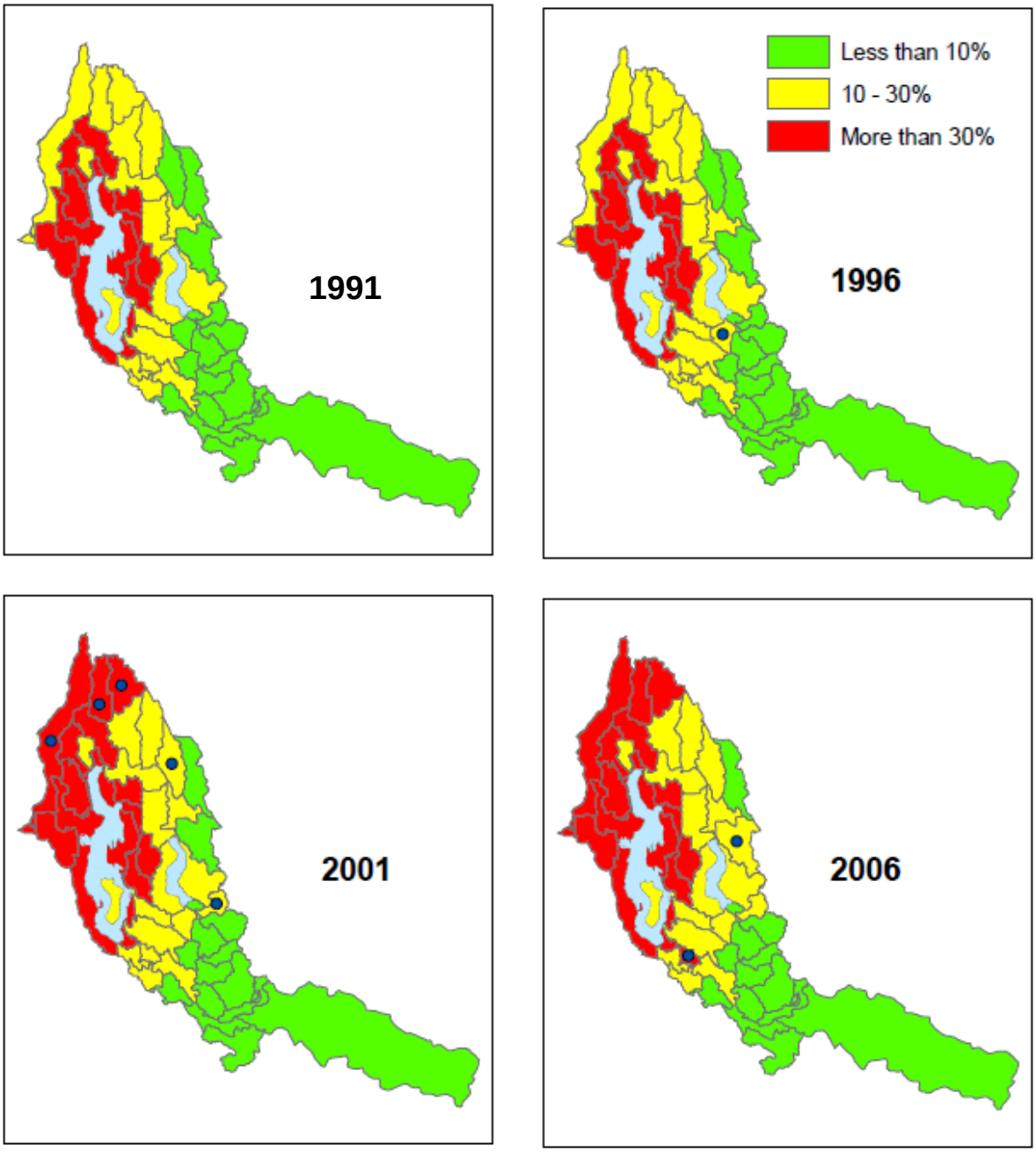
The values in Table C-7 in Appendix C were summed by basin and mapped in three groupings in Figure 12: less than 10 percent impervious (meant to reflect high watershed condition), 10 to 30 percent (medium condition), and greater than 30 percent (low condition). Ten and 30 percent

were chosen as the break points following Leonetti et al. (2005). Figure 12 illustrates the amount of impervious surface area in each basin in each of the study periods based upon C-CAP data.

Using impervious area data (rather than developed area land cover classifications) should be a more comprehensive assessment of the amount of impervious surface in the basin than the developed area assessment for two reasons: (1) because this measure is independent of the land cover class, and (2) because the percentages of impervious surface are estimates of how much impervious area is in each cell, as opposed to using a large range of impervious surface defined by cover classes.

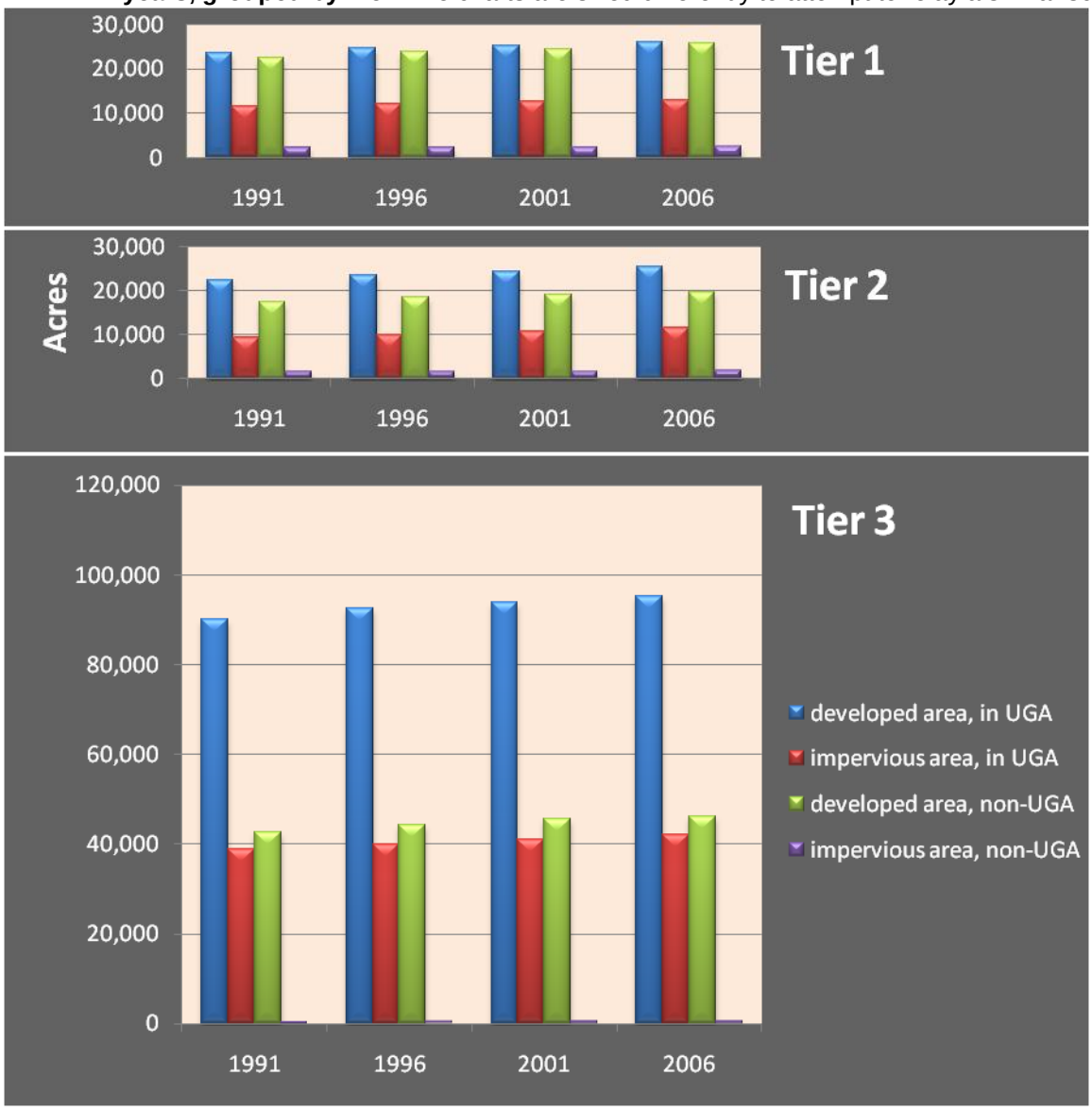
As mentioned in the Methods section, the 1991, 1996, and 2001 impervious data did not include pixels representing less than 20 percent impervious area. Pixels are 98 by 98 feet; therefore, any pixels with fewer than 1920.8 $ft^2$ (0.04 acres) of impervious area were not tabulated. The 0-19 percent impervious data was included in the 2006 dataset; however, it was removed in our analysis in order to make comparisons such as in Figure 12. In 2006, an average of 12 percent of impervious area per basin was in pixels containing less than 20 percent impervious area. This amount of impervious area equates to an average of 1.6 percent of total basin area.

**Figure 12. Amount of impervious area in the subbasins.** Dots within basins indicate those basins that changed categories from the previous data period.




Developed area is based upon 5 land-cover classifications (none of which are assumed to be 100 percent impervious); whereas impervious area can occur in any land cover class. Figure 13 illustrates, by Tier, developed area and impervious area inside and outside the UGA for each of the four study years. Refer back to Figure 11 for composition of developed area in each Tier.

**Figure 13. Developed area and impervious area inside and outside the UGA for each of the study years, grouped by Tier.** The charts are sized differently to attempt to relay a similar scale.



## 4.2 Riparian Area

In those subbasins showing the greatest percentage of forest cover loss between 2001 and 2006 using C-CAP data, we selected a random sample of stream reaches for closer examination. This component of the study was performed at a finer spatial scale than the basin-wide analysis in order to estimate change in riparian areas with greater confidence. In total, we analyzed 54 stream reaches comprising about 22 percent of the salmon-bearing length of each stream.

### 4.2.1 Photo Interpretation

Several potential sources of error were encountered during orthophoto interpretation, including change of resolution of imagery used, change of stream shape, and shift of photo angle or photo registration.

The imagery was captured over several months, a process that resulted in noticeable variation in vegetation in many of the composites. Shifts in photo angle and registration of the 2009 images were mentioned in the results section. There are many example of misalignment along the seam lines of the sector tiles. Because the newer images are not true orthophotos and are instead composites of sector tiles, the registration of future imagery may also not match up with the 2009 imagery. These challenges rendered square-to-square comparison impossible for some subbasins analyzed in this report and will affect comparisons in potential future studies.

Regarding resolution, the 2005 1-foot resolution was consistently challenging to make land cover determinations from, and the 2009 6-inch resolution, although much better than the 1-foot resolution, was also occasionally challenging.

Stream sinuosity – and therefore reach length – is expected to change as channels shift in their floodplain, as channels are straightened either directly or indirectly as the result of development, and as stream restoration projects are constructed. Measured stream miles differed between 2005 and 2009 (Table 18). In addition to changing sinuosity, mapped reach lengths may vary because of mapping mistakes.

**Table 18.Total reach length in subbasins based upon 2005 versus 2009 orthophotos.**

| BASIN | 2005 Length (feet) | 2009 Length (feet) |
|---|---|---|
| East Fork Issaquah | 35,010 | 35,635 |
| Evans | 61,068 | 61,492 |
| Lower Bear | 97,233 | 101,717 |
| Lower North | 71,196 | 70,593 |
| North Fork Issaquah | 9,629 | 9,416 |
| Taylor | 20,953 | 22,584 |
| Upper Bear | 53,468 | 56,877 |
| Upper North | 64,514 | 64,770 |

### 4.2.2 Forest Cover and Impervious Area

Forest cover was lost in some basins and gained in others. Within Tier 1 subbasins, Lower Bear showed a 3.9 percent loss in forest in the riparian area between 2005 and 2009, whereas the other

Tier 1 subbasins all showed a very small overall gain (less than 1 percent). Within Tier 2 subbasins, two showed gain and two showed loss of forest cover.

Impervious area increased in all subbasins in the riparian study. The greatest increase observed was in Lower Bear in Tier 1, followed by Lower North in Tier 2. For Lower Bear, both the impervious area increase and forest cover decrease we documented appeared to be heavily influenced by development in the riparian zone on one reach; subsequent investigation found that this development was permitted under prior (vested) sensitive areas rules. Current rules would have been more restrictive and would likely have resulted in the retention of more forest cover and less impervious area.

Water as a cover class increased overall from 2005 to 2009 in all basins except one, which showed no change. There are several possible reasons for this consistent increase, including:

1. Identifying water in a forested area was more challenging with the 2005 orthophotos because of the lower resolution. If there was a question whether something dark in the forest was a forest shadow or water, “forest” or possibly “shrub” was chosen.
2. Beaver activity has been reported to be on the increase in many areas in WRIA 8, so it is possible some of the increase in open water was a result of beaver dams.
3. Rainfall may have been higher preceding the shooting of the 2009 orthophotos.

Shrub cover decreased from 2005 to 2009 in all subbasins except Upper North Creek, and “other” showed a mix of increase in some subbasins and a decrease in others.

A rough idea of how basin-scale data (C-CAP) compares to the more specific riparian data (hand-characterized) may be informative. Because riparian areas are protected through regulations, in theory the results should show a higher percentage of forest and a lower percentage of impervious area in the riparian areas than in the basins as a whole. However, with few exceptions, that is not what we see (Table 19). Upon closer inspection, it appears that much impervious area in riparian zones are the result of roads built close to streams. For example, East Fork Issaquah Creek is frequently within 165 ft of Interstate 90. It might be a worthwhile future exercise to determine how many of WRIA 8 salmon-bearing stream miles are within 165 ft of roads, which will presumably not be removed. A cursory set of calculations reveals that approximately 27.9 percent of the Chinook-coho reaches in WRIA 8 are 165 feet or closer to mapped roads.

**Table 19. Percent of 165-ft riparian buffer in forest cover and impervious surface, 2005 and 2009, compared with 2006 C-CAP data.**

| | | Forest | | | | Impervious | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Riparian Study | | *C-CAP* | | Riparian Study | | *C-CAP* | |
| **Tier** | **Subbasin** | **2005 % forest** | **2009 % forest** | ***2006 % forest in basin*** | ***2006 % forest in buffer*** | **2005 % imperv.** | **2009 % imperv.** | ***2006 % devel.*** | ***2006 % imperv. in basin*** |
| **1** | Lower Bear | 28.82 | 25.51 | *31* | *2.8* | 11.97 | 14.49 | *53* | *18.61* |
| **1** | East Fork Issaquah | 37.77 | 38.07 | *82* | *1.6* | 15.91 | 16.20 | *13* | *4.77* |
| **1** | North Fork Issaquah | 10.27 | 10.55 | *43* | *0.5* | 31.92 | 32.77 | *46* | *17.69* |
| **1** | Upper Bear | 44.20 | 44.83 | *63* | *2.9* | 3.91 | 4.18 | *26* | *5.68* |
| **2** | Cedar North Rural | 36.58 | 38.07 | *48* | *1.5* | 12.35 | 12.50 | *32* | *6.53* |
| **2** | Evans | 41.12 | 38.89 | *41* | *1.7* | 4.60 | 5.08 | *42* | *11.51* |
| **2** | Lower North | 26.58 | 27.40 | *27* | *1.3* | 16.74 | 17.95 | *67* | *27.21* |
| **2** | Upper North | 47.85 | 46.29 | *19* | *2.2* | 9.68 | 10.13 | *73* | *33.67* |

One of the primary reasons for conducting the riparian analysis was to obtain a more detailed understanding of land cover in riparian areas than can be obtained with C-CAP classification data. The column in Table 19 titled "2006 % forest in 165-ft buffer" shows how much forest was identified in the C-CAP dataset within the 165-foot stream buffer; these numbers are clearly not representative of how much forest is actually present. The finer resolution of the riparian study allowed us to capture small features and patches of habitat that are subsumed by other land cover classes with the C-CAP data. Another case in point is water, which is proportionally greater in area in the riparian study.

Although forest was lost in three of the eight subbasins that were examined in the riparian study, not all loss of forest equated directly to gain in impervious area. Some natural processes were in evidence, including stream channel migration. Observed reasons for change in riparian forest cover include:

1. An area was cleared and developed.
2. A flood event or natural channel migration altered a stream or wetland corridor.
3. Dead trees fell and created a clearing.
4. Small trees interpreted as shrubs in 2005 grew into discernable trees by 2009.

## 4.3 Conclusions

In general, forest cover inside the Urban Growth Area boundaries declined throughout the entire study period, though at a slower rate in the latest period (2001-2006). Outside the UGA, forest cover in aggregate declined at a rate too small to reliably quantify. All subbasins in WRIA 8 showed an increase in developed area from 1991 to 2006. Similar to the slowed trend in forest loss, the trend of increase in developed area slowed in the most recent time period (2001-2006).

Although the continued loss of forest cover inside the UGA is predictable because development is directed into those areas, the riparian area analysis shows that some riparian areas lost forest cover and all gained impervious cover between 2005 and 2009. These changes indicate that more protective actions or more creative solutions may be necessary to maintain these areas in a state that supports natural stream dynamics and salmon conservation.

Although it was beyond the scope of this project to investigate the particular reasons for forest cover loss and impervious cover gain in these potentially sensitive ecological areas, much of the change appeared to be the result of two phenomena: (1) small actions by many individual private landowners, and (2) at least one larger development project constructed under 'vested' development rules (and therefore not subject to the most recent critical areas protections).

These observations suggest at least two categories of actions that might be useful to improve protection of riparian areas as part of a larger strategy: (1) targeted outreach activities focused on improving stewardship of stream areas on private property, and (2) activities geared toward identifying important riparian areas subject to vested development rights, and working with property owners to find acceptable means of protecting and improving riparian function in those areas.

## 4.4 Possible Next Steps

The analyses in this report suggest further investigation may be warranted into whether there has been a shift in the conservation geography of Chinook salmon from that delineated in the 2005 Chinook Recovery Plan. We recommend that possible implications of these analyses on current WRIA 8 Plan strategies, including prioritization of populations or Tier areas, should be considered by the WRIA 8 Technical and Implementation Committees.

The results and analyses presented in this report generate many additional questions that might be useful to address in subsequent studies or reports. The following topics are just some examples of possible future questions to examine:

- Is there additional information about what is causing the increase of increased impervious area in the riparian buffer (legal activities, compliance issues, etc.)?
- Is the increase in impervious area in the riparian buffer seen across all areas within the subbasins or is it concentrated? If it is concentrated in certain areas, what is the reason in those areas? (Localized major development projects?)
- Are small streams more likely than rivers with floodplains to show an increase in impervious area within the buffer? Is there an increase in impervious area in regulated floodplains?
- Is impervious area within riparian buffers related to jurisdiction? If so, is it because of differing regulations or levels of enforcement?
- How might results from this study lead to direct recommendations that Recovery Council might use? Example: If acres of forest cover in regulated buffers is decreasing (by nearly 2 acres/year in sub-sampled areas), by inference, how much riparian restoration is needed on average per year to maintain no net loss in all Chinook/coho reaches, (which assumes no other new regulatory protective or voluntary outreach efforts are started)?
- If new results only partly reflect 2011 "at-risk" areas compared to the earlier watershed evaluation, which locations now are most "at-risk" and can/does the current Salmon Plan strategy address these areas or concept?

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# Appendix A

## Coastal Change Analysis Program (C-CAP) Land Cover Classes

**Attributes are as follows** (asterisk indicates classifications are not found in WRIA 8 during the periods under investigation):

| | |
|---|---|
| 0 | Background |
| 1 | Unclassified (Cloud, Shadow, etc) |
| 2 | High Intensity Developed |
| 3 | Medium Intensity Developed |
| 4 | Low Intensity Developed |
| 5 | Open Space Developed |
| 6 | Cultivated Land |
| 7 | Pasture/Hay |
| 8 | Grassland |
| 9 | Deciduous Forest |
| 10 | Evergreen Forest |
| 11 | Mixed Forest |
| 12 | Scrub/Shrub |
| 13 | Palustrine Forested Wetland |
| 14 | Palustrine Scrub/Shrub Wetland |
| 15 | Palustrine Emergent Wetland |
| 16 | Estuarine Forested Wetland* |
| 17 | Estuarine Scrub/Shrub Wetland* |
| 18 | Estuarine Emergent Wetland |
| 19 | Unconsolidated Shore |
| 20 | Bare Land |
| 21 | Water |
| 22 | Palustrine Aquatic Bed |
| 23 | Estuarine Aquatic Bed |
| 24 | Tundra* |
| 25 | Snow/Ice* |

Sources:

A = NLCD 2001 Land Cover Class Definitions, 2004. http://www.mrlc.gov/nlcd_definitions.asp

B = Dobson, J. et al, NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation, NOAA Technical Report NMFS 123, U.S. Department of Commerce, April 1995.

### 1 Unclassified

This class contains no data due to cloud conditions or data voids.

**2 High Intensity Developed[A]**

Contains little or no vegetation. Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.

**3 Medium Intensity Developed[A]**

Contains substantial amounts of constructed surface mixed with substantial amounts of vegetated surface. Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

**4 Low Intensity Developed[A]**

Contains substantial amounts of constructed surface mixed with substantial amounts of vegetated surface. Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

**5 Open Spaces Developed[A]**

Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

**6 Cultivated Land[B]**

Includes herbaceous (cropland) and woody (e.g., orchards, nurseries, and vineyards) cultivated lands.

**7 Pasture/Hay[A]**

characterized by grasses, legumes or grass-legumes mixtures planted for livestock grazing or the production of sees or hay crops.

**8 Grassland[B]**

Dominated by naturally occurring grasses and non-grasses (forbs) that are not fertilized, cut, tilled, or planted regularly.

**9 Deciduous Forest[B]**

Includes areas dominated by single stemmed, woody vegetation un-branched 0.6 to 1 meter (2 to 3 feet) above the ground and having a height greater than 5 meters (20 feet).

**10 Evergreen Forest[B]**

Includes areas in which more than 67 percent of the trees remain green throughout the year. Both coniferous and broad-leaved evergreens (greater than 5 meters) are included in this category.

### 11 Mixed Forest[B]

Contains all forested areas in which both evergreen and deciduous trees (greater than 5 meters) are growing and neither predominate.

### 12 Scrub/Shrub[B]

Areas dominated by woody vegetation less than 5 meters in height. This class includes true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions.

### 13 Palustrine Forested Wetland[B]

Includes all non-tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 parts per thousand (ppt).

### 14 Palustrine Scrub/Shrub Wetland[B]

Includes all non-tidal wetlands dominated by woody vegetation less than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 ppt.

### 15 Palustrine Emergent Wetland[B]

Includes all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 ppt.

### 16 Estuarine Forest Wetland[B]

Includes all tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is above 0.5 parts per thousand (ppt).

### 17 Estuarine Scrub/Shrub Wetland[B]

Includes all tidal wetlands dominated by woody vegetation less than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is above 0.5 ppt.

### 18 Estuarine Emergent[B]

Characterized by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens) that are present for most of the growing season in most years. Perennial plants usually dominate these wetlands. All water regimes are included except those that are sub-tidal and irregularly exposed.

### 19 Unconsolidated Shore[B]

Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms, such as beaches, bars, and flats, all of which are included in this class.

### 20 Bare Land[B]

Composed of bare soil, rock, sand, silt, gravel, or other earthen material with little or no vegetation.

### 21 Water[B]

Includes all areas of open water with less than 30 percent cover of trees, shrubs, persistent emergent plants, emergent mosses, or lichens.

### 22 Palustrine Aquatic Bed[B]

Includes wetlands and deepwater habitats dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years.

### 23 Estuarine Aquatic Bed[B]

Includes widespread and diverse Algal Beds in the Marine and Estuarine Systems, where they occupy substrates characterized by a wide range of sediment depths and textures. They occur in both the sub-tidal and inter-tidal Subsystems and may grow to depths of 30 m (98 feet). This class includes kelp forests.

### 24 Tundra[B]

Includes treeless cover beyond the latitudinal limit of the boreal forest in pole-ward regions and above the elevation range of the boreal forest in high mountains.

### 25 Snow/Ice[B]

Includes persistent snow and ice that persist for greater portions of the year.

# Appendix B

## Comparison of C-CAP and Simmonds et al. (2004) forest cover data for 2001.

The Leonetti et al. (2005) report used forest cover from the dataset used by Simmonds et al. (2004), which in turn used land cover classifications from Purser et al. (2003). At first glance, the forest cover per basin for a given year (2001, for example) varies wildly from the forest cover in the C-CAP dataset. But upon further examination, the primary differences are caused by different land classifications across characterization methods.

The Purser et al. (2003) classification system includes four different cover classes with forest, with an emphasis on evergreen forest:

1- Mature evergreen forest: Hydrologically mature and contributes to large woody debris (LWD) which is likely to be in excess of 60 cm in diameter and 15.2 m in length. Overlay analysis with Forest Service stand age data defines this class as being at least 100 years old.

2- Medium evergreen forest: Hydrologically mature and does not contribute to LWD, but contributes to woody debris which greater than 10 cm in diameter and 2.0 m in length. Overlay analysis with Forest Service stand age data defines this class as being 27 to 99 years old.

3- Deciduous Stands: Hydrologically mature and in most cases does not contribute to LWD, but contributes to woody debris which greater than 10 cm in diameter and 2.0 m in length.

4- Shrubs and small trees: Hydrologically immature, but may provide small amounts of woody debris which is greater than 10 cm in diameter and 2.0 m in length; contains scrub/shrub, vegetated clearings, industrial forest saplings.

The C-CAP forest data, based on Dobson et al. (1995), include three forest cover classes, and their distinction is forest type: mixed forest, evergreen forest, and deciduous forest. All classes are presumed to be at least 5 meters in height (so, not necessarily mature). The definitions of the three forest cover classes in C-CAP include:

Deciduous Forest: Includes areas dominated by single stemmed, woody vegetation un-branched 0.6 to 1 meter (2 to 3 feet) above the ground and having a height greater than 5 meters (20 feet).

Evergreen Forest: Includes areas in which more than 67 percent of the trees remain green throughout the year. Both coniferous and broad-leaved evergreens (greater than 5 meters) are included in this category.

Mixed Forest: Contains all forested areas in which both evergreen and deciduous trees (greater than 5 meters) are growing and neither predominate.

To be able to compare the forest cover from the two disparate datasets, some amount of combing of cover classes is necessary. See Table B-1.

**Table B1. Comparison of C-CAP and Simmonds et al. (2004) forest cover data for 2001.**

| | | C-CAP data for 2001 | | | | Simmonds et al. (2004) data for 2001 | | |
|---|---|---|---|---|---|---|---|---|
| **Tier** | **Subbasin** | **forest % of basin** | **shrub % of basin** | **Wetland % of basin** | **Combined shrub, forest, and wetland** | **Mature Forest (%)** | **shrub/ small trees % of basin** | **Combined shrub and forest** |
| **1** | Cedar Main Rural | 63 | 3 | 2 | 69 | 46 | 23 | 69 |
| **1** | Cedar Main Urban | 36 | 3 | 5 | 44 | 21 | 26 | 47 |
| **1** | Cottage Lake | 49 | 2 | 5 | 56 | 28 | 31 | 59 |
| **1** | East Fork Issaquah | 83 | 3 | 0 | 87 | 64 | 21 | 85 |
| **1** | Fifteenmile | 89 | 3 | 1 | 92 | 61 | 30 | 91 |
| **1** | Lake Union | 3 | 0 | 0 | 3 | 1 | 4 | 5 |
| **1** | Lower Bear | 31 | 3 | 7 | 41 | 19 | 23 | 42 |
| **1** | Lower Issaquah | 69 | 2 | 6 | 77 | 52 | 24 | 76 |
| **1** | Lower Sammamish Valley | 33 | 1 | 3 | 38 | 17 | 22 | 39 |
| **1** | Middle Issaquah | 65 | 5 | 6 | 76 | 42 | 32 | 74 |
| **1** | North Fork Issaquah | 49 | 4 | 4 | 57 | 31 | 23 | 54 |
| **1** | Upper Bear | 64 | 3 | 6 | 72 | 43 | 28 | 71 |
| **1** | Upper Issaquah | 78 | 5 | 3 | 86 | 49 | 35 | 84 |
| **1** | Upper Sammamish Valley | 17 | 2 | 5 | 24 | 8 | 19 | 27 |
| **2** | Cedar North Rural | 49 | 6 | 6 | 60 | 31 | 32 | 63 |
| **2** | Evans | 42 | 4 | 10 | 56 | 29 | 27 | 56 |
| **2** | Kelsey | 20 | 1 | 2 | 23 | 13 | 24 | 37 |
| **2** | Little Bear | 47 | 2 | 3 | 52 | 26 | 26 | 52 |
| **2** | Lower North | 30 | 1 | 5 | 36 | 15 | 22 | 37 |
| **2** | Mercer Slough | 9 | 1 | 22 | 32 | 7 | 25 | 32 |
| **2** | Rock | 65 | 12 | 3 | 80 | 45 | 33 | 78 |
| **2** | South Kelsey | 14 | 1 | 7 | 21 | 7 | 21 | 28 |
| **2** | Upper Cedar | 82 | 12 | 1 | 94 | 78 | 13 | 91 |
| **2** | Upper North | 20 | 1 | 5 | 26 | 10 | 20 | 30 |
| **2** | Walsh | 86 | 1 | 3 | 91 | 76 | 15 | 91 |
| **3** | Cedar North Urban | 24 | 1 | 1 | 26 | 11 | 21 | 32 |
| **3** | Cedar South Urban | 26 | 1 | 2 | 29 | 16 | 18 | 34 |
| **3** | Coal | 49 | 1 | 1 | 50 | 21 | 33 | 54 |
| **3** | East Lake Sammamish | 41 | 2 | 4 | 47 | 26 | 26 | 52 |
| **3** | East Lake Washington | 24 | 1 | 2 | 27 | 12 | 18 | 30 |
| **3** | Forbes | 20 | 1 | 4 | 25 | 10 | 23 | 33 |
| **3** | Green Lake | 5 | 0 | 1 | 6 | 1 | 7 | 8 |
| **3** | Juanita | 18 | 1 | 2 | 22 | 6 | 21 | 27 |
| **3** | Lower Swamp | 20 | 1 | 5 | 26 | 8 | 20 | 28 |
| **3** | Lyons | 25 | 0 | 1 | 26 | 12 | 22 | 34 |
| **3** | May | 51 | 3 | 2 | 56 | 28 | 28 | 56 |
| **3** | McAleer | 13 | 0 | 1 | 14 | 6 | 17 | 23 |
| **3** | McDonald | 62 | 3 | 3 | 68 | 36 | 31 | 67 |
| **3** | Mercer Island | 30 | 1 | 2 | 32 | 9 | 24 | 33 |
| **3** | Nearshore | 28 | 1 | 2 | 31 | 11 | 16 | 27 |
| **3** | North Lake Washington | 19 | 0 | 1 | 20 | 6 | 17 | 23 |
| **3** | Peterson | 60 | 6 | 8 | 74 | 39 | 31 | 70 |
| **3** | Thornton | 9 | 1 | 0 | 10 | 3 | 13 | 16 |
| **3** | Tibbetts | 73 | 1 | 2 | 77 | 42 | 35 | 77 |
| **3** | Upper Swamp | 23 | 1 | 3 | 27 | 10 | 19 | 29 |
| **3** | West Lake Sammamish | 25 | 1 | 1 | 27 | 15 | 24 | 39 |
| **3** | West Lake Washington | 10 | 0 | 1 | 11 | 4 | 8 | 12 |

# Appendix C

## Results tables from the C-CAP analysis.

**Table C-1. Total area and percent of forest cover in subbasins in each of the four periods of analysis, percent change (% Δ) between periods of analysis, and overall percent change.** "Forest" includes Evergreen Forest, Deciduous Forest, and Mixed Forest classifications from C-CAP program data. Negative values represent areas that lost forest cover during the period. A minus (-) sign in the percent change column indicates forest was lost; a positive number indicates an increase in forest in the subbasin.

| | | | | 1991 | | | 1996 | | | 2001 | | | 2006 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tier | ID | Subbasin | Total Acres in Subbasin | Forest Acres | % | %Δ, 1991 to 1996 | Forest Acres | % | % Δ, 1996 to 2001 | Forest Acres | % | % Δ, 2001 to 2006 | Forest Acres | % | % Δ, 1991 to 2006 |
| 1 | 1 | Cedar Main Rural | 4917.71 | 3251.60 | 66 | -3.58 | 3135.19 | 64 | -0.61 | 3116.01 | 63 | -0.33 | 3105.87 | 63 | -4.5 |
| 1 | 2 | Cedar Main Urban | 8929.40 | 3413.43 | 38 | -3.30 | 3300.77 | 37 | -2.88 | 3205.74 | 36 | -0.78 | 3180.83 | 36 | -6.8 |
| 1 | 3 | Cottage Lake | 8356.10 | 4290.71 | 51 | -1.96 | 4206.49 | 50 | -1.84 | 4129.10 | 49 | -0.43 | 4111.24 | 49 | -4.2 |
| 1 | 4 | East Fork Issaquah | 6054.32 | 5129.19 | 85 | -1.14 | 5070.54 | 84 | -0.52 | 5044.08 | 83 | -2.02 | 4942.22 | 82 | -3.6 |
| 1 | 5 | Fifteenmile | 3082.95 | 2787.28 | 90 | -0.02 | 2786.84 | 90 | -1.91 | 2733.48 | 89 | 0.46 | 2746.05 | 89 | -1.5 |
| 1 | 6 | Lake Union | 8962.76 | 236.35 | 3 | 0.00 | 236.35 | 3 | 0.00 | 236.35 | 3 | 0.00 | 236.35 | 3 | 0.0 |
| 1 | 7 | Lower Bear | 5222.08 | 1799.54 | 34 | -4.45 | 1719.50 | 33 | -5.18 | 1630.43 | 31 | -2.23 | 1594.05 | 31 | -11.4 |
| 1 | 8 | Lower Issaquah | 6462.04 | 4465.11 | 69 | -0.46 | 4444.39 | 69 | -0.31 | 4430.50 | 69 | -0.15 | 4423.66 | 68 | -0.9 |
| 1 | 9 | Lower Sammamish Vly | 7767.37 | 2709.67 | 35 | -4.58 | 2585.54 | 33 | -1.40 | 2549.38 | 33 | -1.38 | 2514.10 | 32 | -7.2 |
| 1 | 10 | Middle Issaquah | 4593.18 | 3102.78 | 68 | -1.51 | 3055.82 | 67 | -1.92 | 2997.17 | 65 | -0.11 | 2993.86 | 65 | -3.5 |
| 1 | 11 | North Fork Issaquah | 2946.67 | 1816.96 | 62 | -5.69 | 1713.55 | 58 | -15.30 | 1451.40 | 49 | -12.53 | 1269.51 | 43 | -30.1 |
| 1 | 12 | Upper Bear | 8859.82 | 5880.80 | 66 | -2.75 | 5719.19 | 65 | -1.09 | 5657.01 | 64 | -1.87 | 5550.96 | 63 | -5.6 |
| 1 | 13 | Upper Issaquah | 9567.67 | 7081.30 | 74 | 2.93 | 7288.99 | 76 | 2.63 | 7480.36 | 78 | -2.66 | 7281.05 | 76 | 2.8 |
| 1 | 14 | Upper Sammamish Vly | 8848.52 | 1809.68 | 20 | -12.40 | 1585.23 | 18 | -2.98 | 1538.05 | 17 | -1.02 | 1522.42 | 17 | -15.3 |
| 2 | 15 | Cedar North Rural | 4808.59 | 2479.27 | 52 | -2.47 | 2417.98 | 50 | -2.89 | 2348.09 | 49 | -1.81 | 2305.53 | 48 | -7.0 |
| 2 | 16 | Evans | 9802.30 | 4592.77 | 47 | -0.32 | 4578.22 | 47 | -9.46 | 4145.20 | 42 | -3.30 | 4008.50 | 41 | -12.7 |
| 2 | 17 | Kelsey | 5290.56 | 1154.86 | 22 | -4.37 | 1104.37 | 21 | -3.45 | 1066.23 | 20 | -0.23 | 1063.80 | 20 | -7.9 |
| 2 | 18 | Little Bear | 9632.46 | 5098.10 | 53 | -7.49 | 4716.45 | 49 | -3.74 | 4540.07 | 47 | -1.23 | 4484.29 | 47 | -12.0 |
| 2 | 19 | Lower North | 9749.81 | 3436.58 | 35 | -8.38 | 3148.64 | 32 | -6.06 | 2957.71 | 30 | -12.11 | 2599.65 | 27 | -24.4 |
| 2 | 20 | Mercer Slough | 195.02 | 21.17 | 11 | 0.00 | 21.17 | 11 | -18.75 | 17.20 | 9 | 0.00 | 17.20 | 9 | -18.8 |
| 2 | 21 | Rock | 9494.05 | 5606.96 | 59 | 11.33 | 6242.16 | 66 | -1.41 | 6153.97 | 65 | -1.13 | 6084.52 | 64 | 8.5 |
| 2 | 22 | South Kelsey | 5136.71 | 773.66 | 15 | -4.53 | 738.60 | 14 | -2.27 | 721.84 | 14 | -0.06 | 721.40 | 14 | -6.8 |
| 2 | 23 | Upper Cedar | 82078.01 | 64874.18 | 79 | 2.20 | 66299.35 | 81 | 1.30 | 67160.31 | 82 | 0.13 | 67248.06 | 82 | 3.7 |
| 2 | 24 | Upper North | 8665.87 | 2203.01 | 25 | -13.63 | 1902.72 | 22 | -8.02 | 1750.15 | 20 | -5.38 | 1656.01 | 19 | -24.8 |
| 2 | 25 | Walsh | 4208.61 | 3614.29 | 86 | 0.08 | 3617.15 | 86 | 0.12 | 3621.34 | 86 | -0.43 | 3605.69 | 86 | -0.2 |
| 3 | 26 | Cedar North Urban | 1777.28 | 603.23 | 34 | -11.44 | 534.22 | 30 | -19.77 | 428.61 | 24 | -18.00 | 351.44 | 20 | -41.7 |
| 3 | 27 | Cedar South Urban | 3394.87 | 980.24 | 29 | -3.31 | 947.83 | 28 | -7.35 | 878.16 | 26 | -6.93 | 817.31 | 24 | -16.6 |

| | | | | 1991 | | | 1996 | | | 2001 | | | 2006 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tier** | **ID** | **Subbasin** | **Total Acres in Subbasin** | **Forest Acres** | **%** | **%Δ, 1991 to 1996** | **Forest Acres** | **%** | **% Δ, 1996 to 2001** | **Forest Acres** | **%** | **% Δ, 2001 to 2006** | **Forest Acres** | **%** | **% Δ, 1991 to 2006** |
| **3** | 28 | Coal | 4130.55 | 2305.97 | 56 | -6.26 | 2161.56 | 52 | -6.83 | 2013.84 | 49 | -3.45 | 1944.39 | 47 | -15.7 |
| **3** | 29 | East Lake Sammamish | 10005.43 | 4865.50 | 49 | -4.64 | 4639.51 | 46 | -11.08 | 4125.35 | 41 | -4.40 | 3943.90 | 39 | -18.9 |
| **3** | 30 | East Lake Washington | 13444.24 | 3407.70 | 25 | -2.00 | 3339.57 | 25 | -1.51 | 3289.30 | 24 | -1.07 | 3254.03 | 24 | -4.5 |
| **3** | 31 | Forbes | 2327.77 | 477.11 | 20 | -2.13 | 466.97 | 20 | -0.24 | 465.87 | 20 | -0.38 | 464.11 | 20 | -2.7 |
| **3** | 32 | Green Lake | 8422.29 | 434.12 | 5 | -0.51 | 431.92 | 5 | 0.00 | 431.92 | 5 | 0.00 | 431.92 | 5 | -0.5 |
| **3** | 33 | Juanita | 4189.59 | 773.21 | 18 | -1.43 | 762.19 | 18 | -0.06 | 761.75 | 18 | 0.00 | 761.75 | 18 | -1.5 |
| **3** | 34 | Lower Swamp | 8080.53 | 1800.42 | 22 | -7.53 | 1664.83 | 21 | -1.67 | 1637.05 | 20 | -7.66 | 1511.59 | 19 | -16.0 |
| **3** | 35 | Lyons | 2671.56 | 664.74 | 25 | -0.20 | 663.42 | 25 | -0.70 | 658.79 | 25 | -1.07 | 651.73 | 24 | -2.0 |
| **3** | 36 | May | 8988.70 | 4957.22 | 55 | -2.23 | 4846.76 | 54 | -5.86 | 4562.56 | 51 | -1.61 | 4488.92 | 50 | -9.4 |
| **3** | 37 | McAleer | 5287.04 | 742.57 | 14 | -5.26 | 703.54 | 13 | -2.04 | 689.21 | 13 | -0.35 | 686.79 | 13 | -7.5 |
| **3** | 38 | McDonald | 3250.00 | 2041.40 | 63 | -0.12 | 2038.98 | 63 | -0.85 | 2021.56 | 62 | -0.03 | 2020.90 | 62 | -1.0 |
| **3** | 39 | Mercer Island | 4062.98 | 1209.10 | 30 | 0.26 | 1212.19 | 30 | -0.09 | 1211.08 | 30 | 0.00 | 1211.08 | 30 | 0.2 |
| **3** | 40 | Nearshore | 21700.60 | 6520.40 | 30 | -5.32 | 6173.81 | 28 | -2.17 | 6039.98 | 28 | -1.22 | 5966.56 | 27 | -8.5 |
| **3** | 41 | North Lake Washington | 1159.31 | 217.39 | 19 | 0.00 | 217.39 | 19 | 0.00 | 217.39 | 19 | -0.41 | 216.51 | 19 | -0.4 |
| **3** | 42 | Peterson | 4112.60 | 2552.91 | 62 | -0.63 | 2536.81 | 62 | -2.72 | 2467.80 | 60 | -1.97 | 2419.30 | 59 | -5.2 |
| **3** | 43 | Thornton | 7232.88 | 659.23 | 9 | -1.44 | 649.75 | 9 | -0.27 | 647.98 | 9 | 0.00 | 647.98 | 9 | -1.7 |
| **3** | 44 | Tibbetts | 3441.14 | 2570.55 | 75 | -1.58 | 2529.98 | 74 | -0.20 | 2524.91 | 73 | -5.04 | 2397.69 | 70 | -6.7 |
| **3** | 45 | Upper Swamp | 7606.56 | 2127.17 | 28 | -10.82 | 1896.99 | 25 | -9.14 | 1723.69 | 23 | -10.55 | 1541.80 | 20 | -27.5 |
| **3** | 46 | West Lake Sammamish | 7762.15 | 2185.59 | 28 | -7.72 | 2016.93 | 26 | -4.62 | 1923.67 | 25 | -1.11 | 1902.28 | 25 | -13.0 |
| **3** | 47 | West Lake Washington | 11604.92 | 1238.20 | 11 | -2.49 | 1207.33 | 10 | -0.82 | 1197.41 | 10 | -1.03 | 1185.07 | 10 | -4.3 |

**Table C-2. Percent change in forest cover in each subbasin/period and over the entire period, ordered by tier, highest to lowest %Δ.**

| Tier | ID | Subbasin | Total Acres in Subbasin | %Δ, 1991 to 1996 | % Δ, 1996 to 2001 | % Δ, 2001 to 2006 | % Δ, 1991 to 2006 |
|---|---|---|---|---|---|---|---|
| 1 | 11 | North Fork Issaquah | 2946.67 | -5.69 | -15.30 | -12.53 | -30.1 |
| 1 | 14 | Upper Sammamish Valley | 8848.52 | -12.40 | -2.98 | -0.30 | -15.3 |
| 1 | 7 | Lower Bear | 5222.08 | -4.45 | -5.18 | -2.23 | -11.4 |
| 1 | 9 | Lower Sammamish Valley | 7767.37 | -4.58 | -1.40 | -1.38 | -7.2 |
| 1 | 2 | Cedar Main Urban | 8929.40 | -3.30 | -2.88 | -0.78 | -6.8 |
| 1 | 12 | Upper Bear | 8859.82 | -2.75 | -1.09 | -1.87 | -5.6 |
| 1 | 1 | Cedar Main Rural | 4917.71 | -3.58 | -0.61 | -0.33 | -4.5 |
| 1 | 3 | Cottage Lake | 8356.10 | -1.96 | -1.84 | -0.43 | -4.2 |
| 1 | 4 | East Fork Issaquah | 6054.32 | -1.14 | -0.52 | -2.02 | -3.6 |
| 1 | 10 | Middle Issaquah | 4593.18 | -1.51 | -1.92 | -0.11 | -3.5 |
| 1 | 5 | Fifteenmile | 3082.95 | -0.02 | -1.91 | 0.46 | -1.5 |
| 1 | 8 | Lower Issaquah | 6462.04 | -0.46 | -0.31 | -0.15 | -0.9 |
| 1 | 6 | Lake Union | 8962.76 | 0.00 | 0.00 | 0.00 | 0.0 |
| 1 | 13 | Upper Issaquah | 9567.67 | 2.93 | 2.63 | -2.66 | 2.8 |
| 2 | 24 | Upper North | 8665.87 | -13.63 | -8.02 | -5.38 | -24.8 |
| 2 | 19 | Lower North | 9749.81 | -8.38 | -6.06 | -12.11 | -24.4 |
| 2 | 20 | Mercer Slough | 195.02 | 0.00 | -18.75 | 0.00 | -18.8 |
| 2 | 16 | Evans | 9802.30 | -0.32 | -9.46 | -3.30 | -12.7 |
| 2 | 18 | Little Bear | 9632.46 | -7.49 | -3.74 | -1.23 | -12.0 |
| 2 | 17 | Kelsey | 5290.56 | -4.37 | -3.45 | -0.23 | -7.9 |
| 2 | 15 | Cedar North Rural | 4808.59 | -2.47 | -2.89 | -1.81 | -7.0 |
| 2 | 22 | South Kelsey | 5136.71 | -4.53 | -2.27 | -0.06 | -6.8 |
| 2 | 25 | Walsh | 4208.61 | 0.08 | 0.12 | -0.43 | -0.2 |
| 2 | 23 | Upper Cedar | 82078.01 | 2.20 | 1.30 | 0.13 | 3.7 |
| 2 | 21 | Rock | 9494.05 | 11.33 | -1.41 | -1.13 | 8.5 |
| 3 | 26 | Cedar North Urban | 1777.28 | -11.44 | -19.77 | -18.00 | -41.7 |
| 3 | 45 | Upper Swamp | 7606.56 | -10.82 | -9.14 | -10.55 | -27.5 |
| 3 | 29 | East Lake Sammamish | 10005.43 | -4.64 | -11.08 | -4.40 | -18.9 |
| 3 | 27 | Cedar South Urban | 3394.87 | -3.31 | -7.35 | -6.93 | -16.6 |
| 3 | 34 | Lower Swamp | 8080.53 | -7.53 | -1.67 | -7.66 | -16.0 |
| 3 | 28 | Coal | 4130.55 | -6.26 | -6.83 | -3.45 | -15.7 |
| 3 | 46 | West Lake Sammamish | 7762.15 | -7.72 | -4.62 | -1.11 | -13.0 |
| 3 | 36 | May | 8988.70 | -2.23 | -5.86 | -1.61 | -9.4 |
| 3 | 40 | Nearshore | 21700.60 | -5.32 | -2.17 | -1.22 | -8.5 |
| 3 | 37 | McAleer | 5287.04 | -5.26 | -2.04 | -0.35 | -7.5 |
| 3 | 44 | Tibbetts | 3441.14 | -1.58 | -0.20 | -5.04 | -6.7 |
| 3 | 42 | Peterson | 4112.60 | -0.63 | -2.72 | -1.97 | -5.2 |
| 3 | 30 | East Lake Washington | 13444.24 | -2.00 | -1.51 | -1.07 | -4.5 |
| 3 | 47 | West Lake Washington | 11604.92 | -2.49 | -0.82 | -1.03 | -4.3 |
| 3 | 31 | Forbes | 2327.77 | -2.13 | -0.24 | -0.38 | -2.7 |
| 3 | 35 | Lyons | 2671.56 | -0.20 | -0.70 | -1.07 | -2.0 |
| 3 | 43 | Thornton | 7232.88 | -1.44 | -0.27 | 0.00 | -1.7 |
| 3 | 33 | Juanita | 4189.59 | -1.43 | -0.06 | 0.00 | -1.5 |
| 3 | 38 | McDonald | 3250.00 | -0.12 | -0.85 | -0.03 | -1.0 |
| 3 | 32 | Green Lake | 8422.29 | -0.51 | 0.00 | 0.00 | -0.5 |
| 3 | 41 | North Lake Washington | 1159.31 | 0.00 | 0.00 | -0.41 | -0.4 |
| 3 | 39 | Mercer Island | 4062.98 | 0.26 | -0.09 | 0.00 | 0.2 |

**Table C-3a. Total forest area change in the urban versus rural portions of WRIA 8 subbasins; urban and rural data all shown together on a single line per subbasin.** (Percentage of forest area shown in parentheses.)

| Tier | Subbasin | 1991 Forest Acres (%) | | 1996 Forest Acres (%) | | 2001 Forest Acres (%) | | 2006 Forest Acres (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | in UGA | outside UGA | in UGA | outside UGA | in UGA | outside UGA | in UGA | outside UGA |
| 1 | Cedar Main Rural | 306 (49) | 2946 (69) | 209 (33) | 2926 (68) | 134 (21) | 2982 (70) | 134 (21) | 2972 (69) |
| 1 | Cedar Main Urban | 1049 (26) | 2364 (49) | 1025 (25) | 2275 (47) | 983 (24) | 2223 (46) | 961 (23) | 2220 (46) |
| 1 | Cottage Lake | 553 (37) | 3738 (54) | 509 (34) | 3698 (54) | 460 (31) | 3667 (53) | 460 (31) | 3651 (53) |
| 1 | East Fork Issaquah | 791 (67) | 4339 (89) | 738 (62) | 4333 (89) | 644 (54) | 4400 (90) | 546 (46) | 4396 (90) |
| 1 | Fifteenmile | | 2787 (90) | | 2787 (90) | | 2733 (89) | | 2746 (89) |
| 1 | Lake Union | 236 (3) | | 236 (3) | | 236 (3) | | 236 (3) | |
| 1 | Lower Bear | 612 (26) | 1187 (42) | 550 (23) | 1170 (41) | 477 (20) | 1153 (41) | 443 (19) | 1151 (41) |
| 1 | Lower Issaquah | 878 (36) | 3587 (89) | 850 (35) | 3594 (89) | 815 (34) | 3615 (90) | 808 (33) | 3616 (90) |
| 1 | Lower Sammamish Valley | 2050 (35) | 660 (35) | 1937 (33) | 648 (34) | 1913 (33) | 637 (34) | 1877 (32) | 637 (34) |
| 1 | Middle Issaquah | | 3103 (68) | | 3056 (67) | | 2997 (65) | | 2994 (65) |
| 1 | North Fork Issaquah | 889 (50) | 928 (78) | 791 (45) | 922 (78) | 538 (30) | 914 (77) | 361 (20) | 909 (77) |
| 1 | Upper Bear | 508 (79) | 5373 (65) | 517 (81) | 5202 (63) | 479 (75) | 5178 (63) | 391 (61) | 5160 (63) |
| 1 | Upper Issaquah | | 7081 (74) | | 7289 (76) | | 7480 (78) | | 7281 (76) |
| 1 | Upper Sammamish Valley | 1470 (20) | 340 (25) | 1257 (17) | 328 (24) | 1211 (16) | 327 (24) | 1207 (16) | 316 (23) |
| 2 | Cedar North Rural | | 2479 (52) | | 2418 (50) | | 2348 (49) | | 2306 (48) |
| 2 | Evans | 1786 (44) | 2807 (49) | 1785 (44) | 2793 (49) | 1443 (35) | 2702 (47) | 1308 (32) | 2702 (47) |
| 2 | Kelsey | 1155 (22) | | 1104 (21) | | 1066 (20) | | 1064 (20) | |
| 2 | Little Bear | 877 (34) | 4221 (60) | 648 (25) | 4068 (58) | 576 (22) | 3964 (56) | 527 (21) | 3957 (56) |
| 2 | Lower North | 3362 (35) | 75 (42) | 3081 (32) | 68 (38) | 2889 (30) | 69 (39) | 2537 (27) | 63 (35) |
| 2 | Mercer Slough | 21 (11) | | 21 (11) | | 17 (9) | | 17 (9) | |
| 2 | Rock | 244 (51) | 5363 (59) | 193 (40) | 6049 (67) | 175 (37) | 5979 (66) | 148 (31) | 5936 (66) |
| 2 | South Kelsey | 774 (15) | | 739 (14) | | 722 (14) | | 721 (14) | |
| 2 | Upper Cedar | | 64874 (79) | | 66299 (81) | | 67160 (82) | | 67248 (82) |
| 2 | Upper North | 2203 (25) | | 1903 (22) | | 1750 (20) | | 1656 (19) | |
| 2 | Walsh | | 3614 (86) | | 3617 (86) | | 3621 (86) | | 3606 (86) |
| 3 | Cedar North Urban | 603 (34) | | 534 (30) | | 429 (24) | | 351 (20) | |
| 3 | Cedar South Urban | 786 (25) | 194 (80) | 754 (24) | 194 (80) | 705 (22) | 173 (71) | 650 (21) | 168 (69) |
| 3 | Coal | 1380 (43) | 926 (98) | 1235 (39) | 927 (99) | 1089 (34) | 925 (98) | 1021 (32) | 923 (98) |
| 3 | East Lake Sammamish | 4664 (48) | 202 (67) | 4445 (46) | 195 (65) | 3933 (41) | 192 (64) | 3753 (39) | 191 (64) |
| 3 | East Lake Washington | 3408 (25) | | 3340 (25) | | 3289 (24) | | 3254 (24) | |
| 3 | Forbes | 477 (20) | | 467 (20) | | 466 (20) | | 464 (20) | |
| 3 | Green Lake | 434 (5) | | 432 (5) | | 432 (5) | | 432 (5) | |
| 3 | Juanita | 773 (18) | | 762 (18) | | 762 (18) | | 762 (18) | |
| 3 | Lower Swamp | 1800 (22) | | 1665 (21) | | 1637 (20) | | 1512 (19) | |

| Tier | Subbasin | 1991 Forest Acres (%) | | 1996 Forest Acres (%) | | 2001 Forest Acres (%) | | 2006 Forest Acres (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | in UGA | outside UGA | in UGA | outside UGA | in UGA | outside UGA | in UGA | outside UGA |
| **3** | Lyons | 665 (25) | | 663 (25) | | 659 (25) | | 652 (24) | |
| **3** | May | 1633 (42) | 3324 (66) | 1536 (39) | 3311 (65) | 1327 (34) | 3235 (64) | 126 (32) | 3228 (64) |
| **3** | McAleer | 743 (14) | | 704 (13) | | 689 (13) | | 687 (13) | |
| **3** | McDonald | | 2041 (63) | | 2039 (63) | | 2022 (62) | | 2021 (62) |
| **3** | Mercer Island | 1209 (30) | | 1212 (30) | | 1211 (30) | | 1211 (30) | |
| **3** | Nearshore | 6520 (30) | | 6174 (28) | | 6040 (28) | | 5967 (27) | |
| **3** | North Lake Washington | 217 (19) | | 217 (19) | | 217 (19) | | 217 (19) | |
| **3** | Peterson | 282 (47) | 2271 (65) | 267 (45) | 2270 (65) | 232 (39) | 2236 (64) | 208 (35) | 2212 (63) |
| **3** | Thornton | 659 (9) | | 650 (9) | | 648 (9) | | 648 (9) | |
| **3** | Tibbetts | 1184 (60) | 1387 (95) | 1145 (58) | 1385 (95) | 1130 (57) | 1396 (95) | 1003 (51) | 1395 (95) |
| **3** | Upper Swamp | 2127 (28) | | 1897 (25) | | 1724 (23) | | 1542 (20) | |
| **3** | West Lake Sammamish | 2153 (28) | 33 (84) | 1984 (26) | 33 (86) | 1891 (24) | 33 (84) | 1870 (24) | 32 (84) |
| **3** | West Lake Washington | 1238 (11) | | 1207 (10) | | 1197 (10) | | 1185 (10) | |

**Table C-3b. Forest area change in Tier 1 and Tier 2 subbasins in WRIA 8 shown separately by location inside vs. outside the Urban Growth Area boundary.** Subbasins are ordered by percent of forest cover lost from 1991-2006.

| | | | | 1991 Forest | | 1996 Forest | | 2001 Forest | | 2006 Forest | | 1991 to 2006 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Tier** | **Subbasin** | **Location relative to UGA** | **Total Acres in Subbasin** | **Acres** | **Percent** | **Acres** | **Percent** | **Acres** | **Percent** | **Acres** | **Percent** | **Total gain/ loss, acres** | **Total gain/ loss, percent** |
| **2** | Lower North | outside UGA | 177 | 75 | 42 | 68 | 38 | 69 | 39 | 63 | 35 | -12 | -15.7 |
| **1** | Upper Sammamish Valley | outside UGA | 1382 | 340 | 25 | 328 | 24 | 327 | 24 | 316 | 23 | -24 | -7.1 |
| **2** | Cedar North Rural | outside UGA | 4809 | 2479 | 52 | 2418 | 50 | 2348 | 49 | 2306 | 48 | -174 | -7.0 |
| **2** | Little Bear | outside UGA | 7069 | 4221 | 60 | 4068 | 58 | 3964 | 56 | 3957 | 56 | -264 | -6.3 |
| **1** | Cedar Main Urban | outside UGA | 4816 | 2364 | 49 | 2275 | 47 | 2223 | 46 | 2220 | 46 | -144 | -6.1 |
| **1** | Upper Bear | outside UGA | 8220 | 5373 | 65 | 5202 | 63 | 5178 | 63 | 5160 | 63 | -213 | -4.0 |
| **2** | Evans | outside UGA | 5712 | 2807 | 49 | 2793 | 49 | 2702 | 47 | 2701 | 47 | -106 | -3.8 |
| **1** | Middle Issaquah | outside UGA | 4593 | 3103 | 68 | 3056 | 67 | 2997 | 65 | 2994 | 65 | -109 | -3.5 |
| **1** | Lower Sammamish Valley | outside UGA | 1897 | 660 | 35 | 648 | 34 | 637 | 34 | 637 | 34 | -23 | -3.5 |
| **1** | Lower Bear | outside UGA | 2836 | 1187 | 42 | 1170 | 41 | 1153 | 41 | 1151 | 41 | -37 | -3.1 |
| **1** | Cottage Lake | outside UGA | 6863 | 3738 | 54 | 3698 | 54 | 3669 | 53 | 3651 | 53 | -87 | -2.3 |
| **1** | North Fork Issaquah | outside UGA | 1183 | 928 | 78 | 922 | 78 | 914 | 77 | 909 | 77 | -20 | -2.1 |
| **1** | Fifteenmile | outside UGA | 3083 | 2787 | 90 | 2787 | 90 | 2733 | 89 | 2746 | 89 | -41 | -1.5 |
| **2** | Walsh | outside UGA | 4209 | 3614 | 86 | 3617 | 86 | 3621 | 86 | 3606 | 86 | -9 | -0.2 |
| **1** | Lower Issaquah | outside UGA | 4031 | 3587 | 89 | 3594 | 89 | 3615 | 90 | 3615 | 90 | 28 | 0.8 |
| **1** | Cedar Main Rural | outside UGA | 4289 | 2946 | 69 | 2926 | 68 | 2982 | 70 | 2972 | 69 | 26 | 0.9 |
| **1** | East Fork Issaquah | outside UGA | 4867 | 4339 | 89 | 4333 | 89 | 4400 | 90 | 4396 | 90 | 57 | 1.3 |
| **1** | Upper Issaquah | outside UGA | 9568 | 7081 | 74 | 7289 | 76 | 7480 | 78 | 7281 | 76 | 200 | 2.8 |
| **2** | Upper Cedar | outside UGA | 82078 | 64874 | 79 | 66299 | 81 | 67160 | 82 | 67248 | 82 | 2374 | 3.7 |
| **2** | Rock | outside UGA | 9016 | 5363 | 59 | 6049 | 67 | 5979 | 66 | 5936 | 66 | 573 | 10.7 |
| | | TOTALS for Outside UGA | 170696 | 121867 | 71% | 123543 | 72 | 124153 | 73 | 123864 | 73 | 1997 | 1.6 |
| | | | | | | | | | | | | | |
| **1** | North Fork Issaquah | in UGA | 1764 | 889 | 50 | 791 | 45 | 538 | 30 | 361 | 20 | -528 | -59.4 |
| **1** | Cedar Main Rural | in UGA | 629 | 306 | 49 | 209 | 33 | 134 | 21 | 134 | 21 | -172 | -56.3 |
| **2** | Little Bear | in UGA | 2564 | 877 | 34 | 648 | 25 | 576 | 22 | 527 | 21 | -350 | -39.9 |
| **2** | Rock | in UGA | 478 | 244 | 51 | 193 | 40 | 175 | 37 | 148 | 31 | -96 | -39.3 |
| **1** | East Fork Issaquah | in UGA | 1188 | 791 | 67 | 738 | 62 | 644 | 54 | 546 | 46 | -244 | -30.9 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | Lower Bear | in UGA | 2386 | 612 | 26 | 550 | 23 | 477 | 20 | 443 | 19 | -169 | -27.6 |
| **2** | Evans | in UGA | 4090 | 1786 | 44 | 1785 | 44 | 1443 | 35 | 1307 | 32 | -479 | -26.8 |
| **2** | Upper North | in UGA | 8666 | 2203 | 25 | 1903 | 22 | 1750 | 20 | 1656 | 19 | -547 | -24.8 |
| **2** | Lower North | in UGA | 9573 | 3362 | 35 | 3081 | 32 | 2889 | 30 | 2537 | 27 | -825 | -24.5 |
| **1** | Upper Bear | in UGA | 640 | 508 | 79 | 517 | 81 | 479 | 75 | 391 | 61 | -117 | -23.0 |
| **2** | Mercer Slough | in UGA | 195 | 21 | 11 | 21 | 11 | 17 | 9 | 17 | 9 | -4 | -18.8 |
| **1** | Upper Sammamish Valley | in UGA | 7467 | 1470 | 20 | 1257 | 17 | 1211 | 16 | 1207 | 16 | -263 | -17.9 |
| **1** | Cottage Lake | in UGA | 1494 | 553 | 37 | 509 | 34 | 460 | 31 | 460 | 31 | -92 | -16.7 |
| **1** | Lower Sammamish Valley | in UGA | 5870 | 2050 | 35 | 1937 | 33 | 1913 | 33 | 1877 | 32 | -172 | -8.4 |
| **1** | Cedar Main Urban | in UGA | 4113 | 1049 | 26 | 1025 | 25 | 983 | 24 | 961 | 23 | -89 | -8.4 |
| **2** | Kelsey | in UGA | 5291 | 1155 | 22 | 1104 | 21 | 1066 | 20 | 1064 | 20 | -91 | -7.9 |
| **1** | Lower Issaquah | in UGA | 2431 | 878 | 36 | 850 | 35 | 815 | 34 | 808 | 33 | -69 | -7.9 |
| **2** | South Kelsey | in UGA | 5137 | 774 | 15 | 739 | 14 | 722 | 14 | 721 | 14 | -52 | -6.8 |
| | | TOTALS for Inside UGA | 63973 | 19526 | 31% | 17856 | 28 | 16292 | 25 | 15167 | 24 | -4360 | -22.3 |

**Table C-4. Evergreen forest cover inside and outside the UGA in each of the study years.**

| Tier | Subbasin | 1991 | | 1996 | | 2001 | | 2006 | |
|---|---|---|---|---|---|---|---|---|---|
| | | UGA | non-UGA | UGA | non-UGA | UGA | non-UGA | UGA | non-UGA |
| 1 | Cedar Main Rural | 190 | 1,618 | 95 | 1,586 | 30 | 1,586 | 30 | 1,583 |
| 1 | Cedar Main Urban | 202 | 393 | 186 | 345 | 172 | 329 | 167 | 329 |
| 1 | Cottage Lake | 305 | 2,197 | 282 | 2,177 | 255 | 2,163 | 255 | 2,146 |
| 1 | East Fork Issaquah | 389 | 1,895 | 340 | 1,885 | 287 | 1,921 | 274 | 1,921 |
| 1 | Fifteenmile | 0 | 1,397 | | 1,396 | | 1,331 | | 1,344 |
| 1 | Lake Union | 71 | 0 | 71 | 0 | 71 | 0 | 71 | 0 |
| 1 | Lower Bear | 229 | 504 | 199 | 504 | 166 | 499 | 155 | 497 |
| 1 | Lower Issaquah | 224 | 1,463 | 219 | 1,464 | 211 | 1,473 | 211 | 1,473 |
| 1 | Lower Sammamish Valley | 571 | 361 | 550 | 360 | 548 | 349 | 547 | 349 |
| 1 | Middle Issaquah | 0 | 681 | | 660 | | 625 | | 624 |
| 1 | North Fork Issaquah | 362 | 179 | 267 | 173 | 185 | 172 | 159 | 172 |
| 1 | Upper Bear | 305 | 2,284 | 304 | 2,163 | 285 | 2,148 | 262 | 2,143 |
| 1 | Upper Issaquah | | 2,707 | | 2,762 | | 2,761 | | 2,639 |
| 1 | Upper Sammamish Valley | 528 | 150 | 457 | 148 | 419 | 146 | 415 | 146 |
| 2 | Cedar North Rural | | 384 | | 324 | | 314 | | 311 |
| 2 | Evans | 580 | 749 | 573 | 724 | 450 | 689 | 410 | 689 |
| 2 | Kelsey | 730 | 0 | 701 | 0 | 689 | 0 | 689 | 0 |
| 2 | Little Bear | 374 | 1,877 | 250 | 1,800 | 225 | 1,751 | 214 | 1,749 |
| 2 | Lower North | 1307 | 40 | 1159 | 40 | 1065 | 40 | 951 | 35 |
| 2 | Mercer Slough | 6 | 0 | 6 | 0 | 3 | 0 | 3 | 0 |
| 2 | Rock | 125 | 3,253 | 86 | 3,488 | 72 | 3,158 | 48 | 3,129 |
| 2 | South Kelsey | 247 | 0 | 236 | 0 | 228 | 0 | 228 | 0 |
| 2 | Upper Cedar | | 59,366 | | 60,745 | | 61,549 | | 61,639 |
| 2 | Upper North | 1045 | 0 | 896 | 0 | 802 | 0 | 759 | 0 |
| 2 | Walsh | | 2,273 | | 2,275 | | 2,277 | | 2,260 |
| 3 | Cedar North Urban | 152 | 0 | 107 | 0 | 85 | 0 | 74 | 0 |
| 3 | Cedar South Urban | 121 | 63 | 99 | 63 | 95 | 63 | 88 | 62 |
| 3 | Coal | 147 | 5 | 124 | 5 | 117 | 5 | 116 | 5 |
| 3 | East Lake Sammamish | | 1,581 | | 1,420 | | 1,257 | | 1,210 |
| 3 | East Lake Washington | | 1,537 | | 1,510 | | 1,500 | | 1,480 |
| 3 | Forbes | 235 | 0 | 233 | 0 | 233 | 0 | 233 | 0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | Green Lake | 163 | 0 | 160 | 0 | 160 | 0 | 160 | 0 |
| 3 | Juanita | 263 | 0 | 259 | 0 | 258 | 0 | 258 | 0 |
| 3 | Lower Swamp | 576 | 0 | 532 | 0 | 507 | 0 | 475 | 0 |
| 3 | Lyons | 323 | 0 | 321 | 0 | 321 | 0 | 321 | 0 |
| 3 | May | 363 | 420 | 327 | 408 | 286 | 391 | 279 | 391 |
| 3 | McAleer | 376 | 0 | 354 | 0 | 353 | 0 | 352 | 0 |
| 3 | McDonald | | 308 | | 298 | | 278 | | 278 |
| 3 | Mercer Island | 431 | 0 | 432 | 0 | 431 | 0 | 431 | 0 |
| 3 | Nearshore | 3015 | 14 | 2852 | 14 | 2791 | 14 | 2764 | 14 |
| 3 | North Lake Washington | 51 | 0 | 51 | 0 | 51 | 0 | 51 | 0 |
| 3 | Peterson | 101 | 379 | 88 | 375 | 69 | 371 | 62 | 368 |
| 3 | Thornton | 361 | 0 | 351 | 0 | 351 | 0 | 351 | 0 |
| 3 | Tibbetts | 153 | 192 | 137 | 191 | 132 | 194 | 119 | 194 |
| 3 | Upper Swamp | 572 | 0 | 513 | 0 | 475 | 0 | 430 | 0 |
| 3 | West Lake Sammamish | 821 | 1 | 720 | 1 | 695 | 1 | 694 | 1 |
| 3 | West Lake Washington | 258 | 0 | 254 | 0 | 254 | 0 | 254 | 0 |

**Table C-5. Forest to developed area conversion in WRIA 8, grouped by Tier.**

| Tier | Forest Conversion Class Name | Acres 1991 - 1996 | Acres 1996 - 2001 | Acres 2001 - 2006 |
|---|---|---|---|---|
| 1 | Deciduous Forest to Bare Land | 0.0 | 0.88 | 20.72 |
| | Deciduous Forest to Developed Open Space | 36.16 | 14.11 | 5.95 |
| | Deciduous Forest to High Intensity Developed | 14.55 | 1.10 | 0.44 |
| | Deciduous Forest to Low Intensity Developed | 43.65 | 13.89 | 4.85 |
| | Deciduous Forest to Medium Intensity Developed | 35.28 | 5.51 | 14.77 |
| | Evergreen Forest to Bare Land | 32.41 | 122.81 | 20.06 |
| | Evergreen Forest to Developed Open Space | 74.96 | 54.90 | 4.63 |
| | Evergreen Forest to High Intensity Developed | 28.22 | 15.21 | 4.63 |
| | Evergreen Forest to Low Intensity Developed | 247.60 | 120.60 | 24.91 |
| | Evergreen Forest to Medium Intensity Developed | 183.44 | 55.12 | 23.59 |
| | Mixed Forest to Bare Land | 7.50 | 69.67 | 48.73 |
| | Mixed Forest to Developed Open Space | 50.27 | 48.51 | 31.97 |
| | Mixed Forest to High Intensity Developed | 40.79 | 14.33 | 13.67 |
| | Mixed Forest to Low Intensity Developed | 164.04 | 99.21 | 72.10 |
| | Mixed Forest to Medium Intensity Developed | 112.88 | 39.24 | 130.08 |
| | Tier 1 Total | 1071.74 | 675.10 | 421.11 |
| 2 | Deciduous Forest to Bare Land | 4.19 | 3.53 | 1.32 |
| | Deciduous Forest to Developed Open Space | 22.93 | 9.26 | 12.35 |
| | Deciduous Forest to High Intensity Developed | 9.70 | 1.32 | 10.36 |
| | Deciduous Forest to Low Intensity Developed | 23.37 | 10.14 | 38.80 |
| | Deciduous Forest to Medium Intensity Developed | 20.50 | 3.31 | 60.85 |
| | Evergreen Forest to Bare Land | 30.87 | 62.17 | 21.83 |
| | Evergreen Forest to Developed Open Space | 79.15 | 92.82 | 9.04 |
| | Evergreen Forest to High Intensity Developed | 46.74 | 19.62 | 18.30 |
| | Evergreen Forest to Low Intensity Developed | 249.80 | 195.56 | 82.02 |
| | Evergreen Forest to Medium Intensity Developed | 205.93 | 94.81 | 131.18 |
| | Mixed Forest to Bare Land | 14.55 | 54.02 | 13.23 |
| | Mixed Forest to Developed Open Space | 61.07 | 106.27 | 21.17 |
| | Mixed Forest to High Intensity Developed | 40.13 | 20.95 | 25.80 |
| | Mixed Forest to Low Intensity Developed | 169.55 | 186.30 | 103.84 |
| | Mixed Forest to Medium Intensity Developed | 147.28 | 146.40 | 166.02 |
| | Tier 2 Total | 1125.76 | 1006.48 | 716.11 |
| 3 | Deciduous Forest to Bare Land | 5.07 | 0.66 | 4.407 |
| | Deciduous Forest to Developed Open Space | 43.79 | 16.08 | 16.739 |
| | Deciduous Forest to High Intensity Developed | 23.06 | 2.27 | 14.752 |
| | Deciduous Forest to Low Intensity Developed | 54.10 | 21.20 | 77.053 |
| | Deciduous Forest to Medium Intensity Developed | 58.52 | 8.09 | 125.569 |
| | Evergreen Forest to Bare Land | 21.17 | 5.92 | 1.762 |
| | Evergreen Forest to Developed Open Space | 49.38 | 74.45 | 7.268 |
| | Evergreen Forest to High Intensity Developed | 48.91 | 19.84 | 7.625 |
| | Evergreen Forest to Low Intensity Developed | 318.21 | 214.42 | 78.206 |
| | Evergreen Forest to Medium Intensity Developed | 318.11 | 114.37 | 112.002 |
| | Mixed Forest to Bare Land | 13.45 | 20.72 | 20.499 |
| | Mixed Forest to Developed Open Space | 143.78 | 151.54 | 32.021 |
| | Mixed Forest to High Intensity Developed | 50.14 | 45.62 | 28.215 |
| | Mixed Forest to Low Intensity Developed | 292.61 | 405.94 | 140.934 |
| | Mixed Forest to Medium Intensity Developed | 259.79 | 311.71 | 245.939 |
| | Tier 3 Total | 1700.10 | 1412.81 | 912.991 |
| | *Grand Total* | **3897.60** | **3094.39** | **2050.21** |

**Table C-6. Total developed area and percent in subbasins in each of the four years of analysis and rate of change (ROC, expressed in acres/year) from 1991 to 2006.** Developed area is defined as bare land, developed open space, low density developed, medium-density developed, and high-density developed based on C-CAP classification.

| Tier | Subbasin | Acres in Subbasin | 1991 | | 1996 | | 2001 | | 2006 | | ROC (ac/yr) 1991-2006 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | acres | % | acres | % | acres | % | acres | % | |
| 1 | North Fork Issaquah | 2946.67 | 757 | 26 | 902 | 31 | 1030 | 35 | 1349 | 46 | 39.5 |
| 1 | Cedar Main Urban | 8929.40 | 4058 | 45 | 4131 | 46 | 4245 | 48 | 4539 | 51 | 32.1 |
| 1 | Upper Sammamish Vlly | 8848.52 | 5447 | 62 | 5690 | 64 | 5762 | 65 | 5812 | 66 | 24.3 |
| 1 | Upper Bear | 8859.82 | 1959 | 22 | 2166 | 24 | 2228 | 25 | 2308 | 26 | 23.2 |
| 1 | Lower Bear | 5222.08 | 2495 | 48 | 2635 | 50 | 2713 | 52 | 2790 | 53 | 19.7 |
| 1 | Lower Sammamish Vlly | 7767.37 | 4214 | 54 | 4401 | 57 | 4477 | 58 | 4499 | 58 | 19.0 |
| 1 | Cedar Main Rural | 4917.71 | 1112 | 23 | 1255 | 26 | 1329 | 27 | 1387 | 28 | 18.3 |
| 1 | East Fork Issaquah | 6054.32 | 559 | 9 | 584 | 10 | 643 | 11 | 802 | 13 | 16.2 |
| 1 | Cottage Lake | 8356.10 | 3288 | 39 | 3420 | 41 | 3508 | 42 | 3510 | 42 | 14.8 |
| 1 | Lower Issaquah | 6462.04 | 1182 | 18 | 1284 | 20 | 1337 | 21 | 1348 | 21 | 11.1 |
| 1 | Upper Issaquah | 9567.67 | 611 | 6 | 639 | 7 | 686 | 7 | 686 | 7 | 5.0 |
| 1 | Middle Issaquah | 4593.18 | 680 | 15 | 700 | 15 | 719 | 16 | 748 | 16 | 4.6 |
| 1 | Fifteenmile | 3082.95 | 188 | 6 | 189 | 6 | 202 | 7 | 197 | 6 | 0.6 |
| 1 | Lake Union | 8962.76 | 7829 | 87 | 7829 | 87 | 7837 | 87 | 7837 | 87 | 0.5 |
| 2 | Lower North | 9749.81 | 5468 | 56 | 5774 | 59 | 6054 | 62 | 6539 | 67 | 71.4 |
| 2 | Evans | 9802.30 | 3233 | 33 | 3430 | 35 | 3716 | 38 | 4091 | 42 | 57.2 |
| 2 | Little Bear | 9632.46 | 3868 | 40 | 4241 | 44 | 4495 | 47 | 4551 | 47 | 45.5 |
| 2 | Upper North | 8665.87 | 5717 | 66 | 6013 | 69 | 6204 | 72 | 6347 | 73 | 42.0 |
| 2 | Rock | 9494.05 | 662 | 7 | 920 | 10 | 1020 | 11 | 1277 | 13 | 41.0 |
| 2 | Upper Cedar | 82078.01 | 832 | 1 | 1024 | 1 | 1059 | 1 | 1059 | 1 | 15.1 |
| 2 | Cedar North Rural | 4808.59 | 1382 | 29 | 1418 | 29 | 1492 | 31 | 1536 | 32 | 10.3 |
| 2 | Kelsey | 5290.56 | 3948 | 75 | 4004 | 76 | 4049 | 77 | 4049 | 77 | 6.7 |
| 2 | South Kelsey | 5136.71 | 3969 | 77 | 4009 | 78 | 4026 | 78 | 4027 | 78 | 3.8 |
| 2 | Mercer Slough | 195.02 | 123 | 63 | 123 | 63 | 128 | 65 | 128 | 65 | 0.3 |
| 2 | Walsh | 4208.61 | 228 | 5 | 231 | 5 | 231 | 5 | 231 | 5 | 0.2 |
| 3 | East Lake Sammamish | 10005.43 | 4072 | 41 | 4480 | 45 | 4966 | 50 | 5172 | 52 | 73.3 |
| 3 | Upper Swamp | 7606.56 | 4985 | 66 | 5242 | 69 | 5467 | 72 | 5668 | 75 | 45.5 |
| 3 | Nearshore | 21700.60 | 14101 | 65 | 14505 | 67 | 14628 | 67 | 14717 | 68 | 41.1 |
| 3 | May | 8988.70 | 3348 | 37 | 3484 | 39 | 3721 | 41 | 3811 | 42 | 30.9 |
| 3 | West Lake Sammamish | 7762.15 | 5278 | 68 | 5531 | 71 | 5620 | 72 | 5636 | 73 | 23.9 |
| 3 | Coal | 4130.55 | 1709 | 41 | 1867 | 45 | 1972 | 48 | 2029 | 49 | 21.3 |
| 3 | Lower Swamp | 8080.53 | 5800 | 72 | 5957 | 74 | 5985 | 74 | 6117 | 76 | 21.1 |
| 3 | Cedar North Urban | 1777.28 | 1131 | 64 | 1202 | 68 | 1252 | 70 | 1405 | 79 | 18.2 |
| 3 | Cedar South Urban | 3394.87 | 2198 | 65 | 2318 | 68 | 2355 | 69 | 2442 | 72 | 16.3 |
| 3 | East Lake Washington | 13444.24 | 9160 | 68 | 9255 | 69 | 9304 | 69 | 9344 | 70 | 12.3 |
| 3 | Tibbetts | 3441.14 | 646 | 19 | 723 | 21 | 735 | 21 | 824 | 24 | 11.9 |
| 3 | Peterson | 4112.60 | 707 | 17 | 737 | 18 | 790 | 19 | 829 | 20 | 8.1 |
| 3 | McDonald | 3250.00 | 667 | 21 | 680 | 21 | 700 | 22 | 782 | 24 | 7.7 |
| 3 | West Lake Washington | 11604.92 | 10177 | 88 | 10250 | 88 | 10264 | 88 | 10277 | 89 | 6.7 |
| 3 | McAleer | 5287.04 | 4362 | 83 | 4405 | 83 | 4430 | 84 | 4433 | 84 | 4.7 |
| 3 | Juanita | 4189.59 | 3238 | 77 | 3262 | 78 | 3269 | 78 | 3269 | 78 | 2.0 |
| 3 | Green Lake | 8422.29 | 7559 | 90 | 7566 | 90 | 7581 | 90 | 7581 | 90 | 1.5 |
| 3 | Mercer Island | 4062.98 | 2624 | 65 | 2645 | 65 | 2646 | 65 | 2646 | 65 | 1.5 |
| 3 | Thornton | 7232.88 | 6492 | 90 | 6511 | 90 | 6513 | 90 | 6513 | 90 | 1.4 |
| 3 | Forbes | 2327.77 | 1722 | 74 | 1732 | 74 | 1739 | 75 | 1741 | 75 | 1.2 |
| 3 | Lyons | 2671.56 | 1963 | 73 | 1965 | 74 | 1969 | 74 | 1976 | 74 | 0.9 |
| 3 | North Lake Washington | 1159.31 | 916 | 79 | 916 | 79 | 916 | 79 | 921 | 79 | 0.3 |

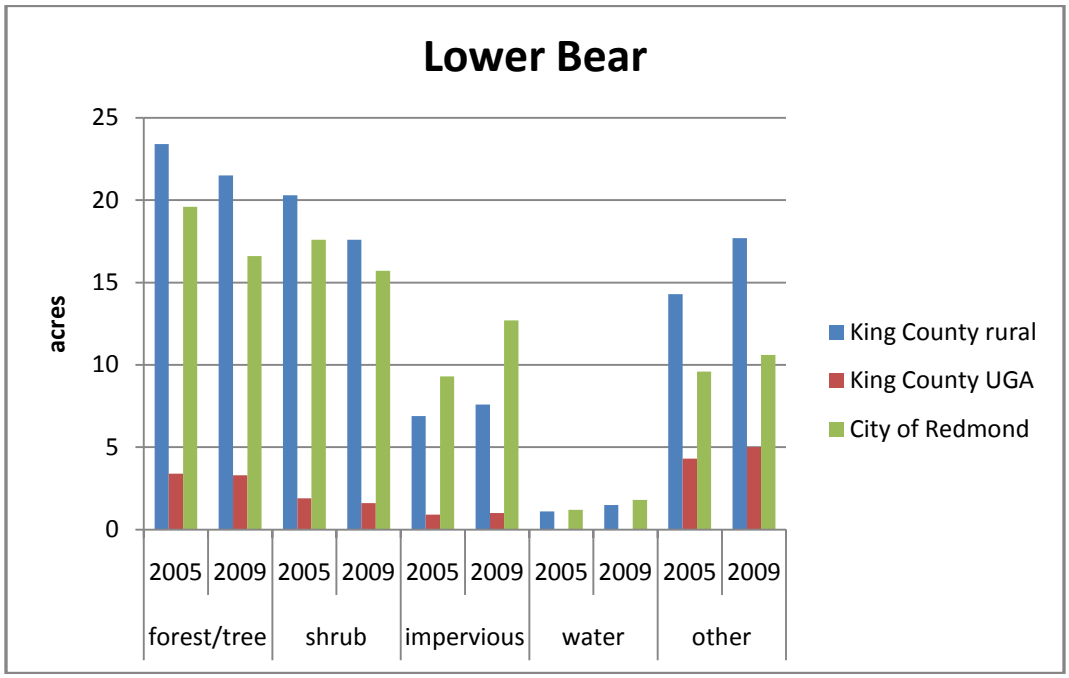
**Table C-7. Total C-CAP impervious area and percent in subbasins in each of the four years of analysis.** Note that percentages are of the urban or rural portion of the basin and not of the entire subbasin.

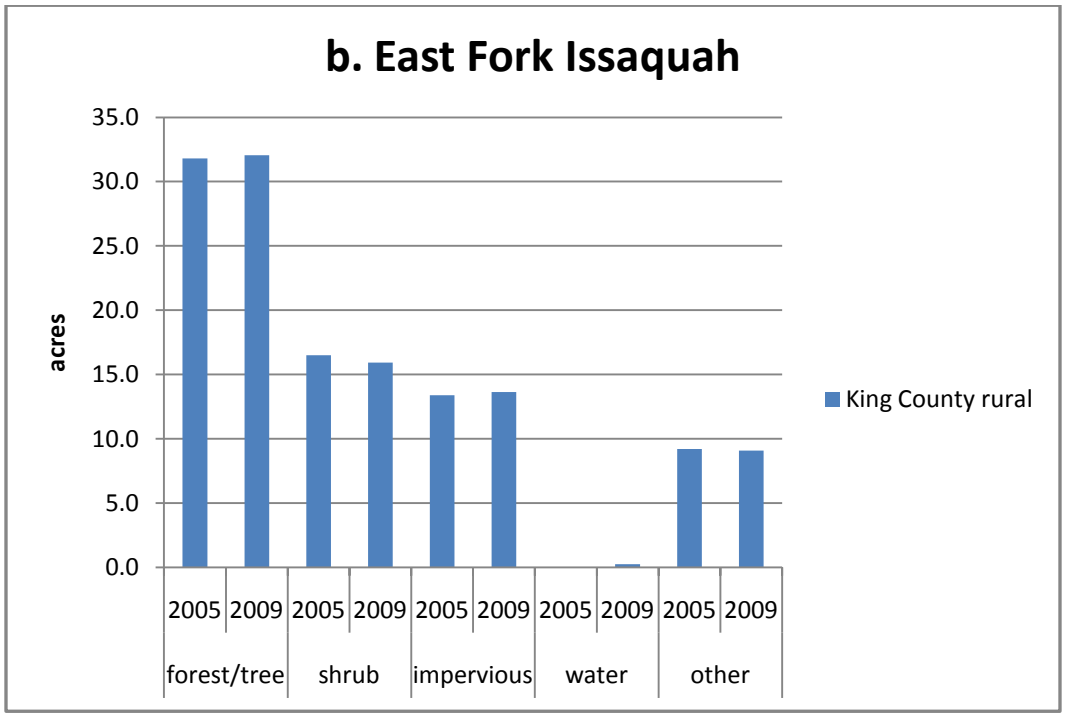
| | | | URBAN 1991 | | RURAL 1991 | | URBAN 1996 | | RURAL 1996 | | URBAN 2001 | | RURAL 2001 | | URBAN 2006 | | RURAL 2006 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Tier | SUBBASIN | ACRES | % | ACRES | % | ACRES | % | ACRES | % | ACRES | % | ACRES | % | ACRES | % | ACRES | % |
| 1 | 1 | Cedar Main Rural | 89.4 | 14.2 | 171.2 | 4.0 | 133.9 | 21.2 | 175.5 | 4.1 | 166.5 | 26.4 | 176.5 | 4.1 | 185.4 | 29.4 | 192.0 | 4.5 |
| 2 | 1 | Cedar Main Urban | 1262.3 | 30.7 | 288.2 | 6.0 | 1281.2 | 31.1 | 289.3 | 6.0 | 1338.9 | 32.5 | 295.8 | 6.1 | 1397.3 | 34.0 | 294.9 | 6.1 |
| 3 | 1 | Cottage Lake | 266.3 | 17.8 | 508.3 | 7.4 | 288.9 | 19.3 | 525.5 | 7.7 | 323.3 | 21.6 | 527.5 | 7.7 | 327.5 | 21.9 | 531.8 | 7.8 |
| 4 | 1 | East Fork Issaquah | 128.5 | 10.9 | 97.9 | 2.0 | 130.0 | 11.0 | 97.9 | 2.0 | 130.0 | 11.0 | 98.8 | 2.0 | 177.1 | 15.0 | 111.8 | 2.3 |
| 5 | 1 | Fifteenmile | | | 44.2 | 1.4 | | | 44.5 | 1.4 | | | 48.9 | 1.6 | | | 49.3 | 1.6 |
| 6 | 1 | Lake Union | 5178.0 | 57.8 | | | 5178.0 | 57.8 | | | 5178.7 | 57.8 | | | 5184.2 | 57.8 | | |
| 7 | 1 | Lower Bear | 561.1 | 23.5 | 175.7 | 6.2 | 600.0 | 25.1 | 190.2 | 6.7 | 700.9 | 29.3 | 192.1 | 6.8 | 771.9 | 32.3 | 199.8 | 7.1 |
| 8 | 1 | Lower Issaquah | 366.8 | 15.1 | 32.1 | 0.8 | 429.3 | 17.6 | 32.1 | 0.8 | 470.1 | 19.3 | 32.4 | 0.8 | 483.3 | 19.9 | 33.3 | 0.8 |
| 9 | 1 | Lower Sammamish Valley | 1430.9 | 24.4 | 171.3 | 9.0 | 1524.4 | 26.0 | 173.8 | 9.2 | 1583.9 | 27.0 | 178.2 | 9.4 | 1587.7 | 27.0 | 179.4 | 9.5 |
| 10 | 1 | Middle Issaquah | | | 137.4 | 3.0 | | | 140.9 | 3.1 | | | 149.3 | 3.3 | | | 151.0 | 3.3 |
| 11 | 1 | North Fork Issaquah | 189.0 | 10.7 | 14.9 | 1.3 | 258.0 | 14.6 | 20.3 | 1.7 | 275.5 | 15.6 | 22.8 | 1.9 | 498.6 | 28.3 | 22.9 | 1.9 |
| 12 | 1 | Upper Bear | 2.5 | 0.4 | 390.2 | 4.8 | 4.2 | 0.7 | 449.6 | 5.5 | 6.6 | 1.0 | 456.4 | 5.6 | 42.0 | 6.6 | 461.1 | 5.6 |
| 13 | 1 | Upper Issaquah | | | 134.2 | 1.4 | | | 151.2 | 1.6 | | | 156.8 | 1.6 | | | 158.8 | 1.7 |
| 14 | 1 | Upper Sammamish Valley | 2151.8 | 28.8 | 95.6 | 6.9 | 2282.0 | 30.6 | 98.9 | 7.2 | 2366.8 | 31.7 | 98.9 | 7.2 | 2401.9 | 32.2 | 102.0 | 7.4 |
| 15 | 2 | Cedar North Rural | | | 262.1 | 5.4 | | | 268.4 | 5.6 | | | 274.8 | 5.7 | | | 314.1 | 6.5 |
| 16 | 2 | Evans | 370.2 | 9.1 | 331.5 | 5.8 | 466.1 | 11.4 | 349.1 | 6.1 | 558.0 | 13.6 | 356.8 | 6.2 | 762.3 | 18.6 | 366.2 | 6.4 |
| 17 | 2 | Kelsey | 1834.8 | 34.7 | | | 1874.6 | 35.4 | | | 1900.5 | 35.9 | | | 1908.3 | 36.1 | | |
| 18 | 2 | Little Bear | 763.8 | 29.4 | 421.6 | 6.0 | 871.5 | 33.6 | 449.9 | 6.4 | 964.6 | 37.1 | 468.6 | 6.7 | 1001.6 | 38.6 | 483.1 | 6.9 |
| 19 | 2 | Lower North | 1792.2 | 18.7 | 13.4 | 8.0 | 1944.5 | 20.3 | 13.8 | 8.2 | 2253.2 | 23.5 | 13.8 | 8.2 | 2638.3 | 27.5 | 15.0 | 8.9 |
| 20 | 2 | Mercer Slough | 51.9 | 26.6 | | | 51.9 | 26.6 | | | 56.1 | 28.7 | | | 56.4 | 28.9 | | |
| 21 | 2 | Rock | 45.4 | 9.5 | 156.2 | 1.7 | 71.3 | 14.9 | 177.9 | 2.0 | 101.4 | 21.2 | 206.7 | 2.3 | 139.5 | 29.2 | 206.2 | 2.3 |
| 22 | 2 | South Kelsey | 2031.5 | 39.5 | | | 2052.9 | 40.0 | | | 2066.8 | 40.2 | | | 2072.7 | 40.4 | | |
| 23 | 2 | Upper Cedar | | | 255.2 | 0.3 | | | 298.3 | 0.4 | | | 320.6 | 0.4 | | | 321.9 | 0.4 |
| 24 | 2 | Upper North | 2436.6 | 28.1 | | | 2584.7 | 29.8 | | | 2762.1 | 31.9 | | | 2917.8 | 33.7 | | |
| 25 | 2 | Walsh | | | 47.0 | 1.1 | | | 48.4 | 1.1 | | | 49.6 | 1.2 | | | 50.1 | 1.2 |
| 26 | 3 | Cedar North Urban | 349.8 | 19.7 | | | 378.2 | 21.3 | | | 434.2 | 24.4 | | | 590.6 | 33.2 | | |
| 27 | 3 | Cedar South Urban | 819.7 | 26.0 | 7.5 | 3.1 | 857.2 | 27.2 | 7.9 | 3.3 | 865.4 | 27.5 | 12.7 | 5.3 | 930.4 | 29.5 | 12.6 | 5.2 |
| 28 | 3 | Coal | 624.6 | 19.6 | 0.3 | 0.0 | 650.4 | 20.4 | 0.3 | 0.0 | 716.6 | 22.5 | 0.3 | 0.0 | 726.6 | 22.8 | 0.5 | 0.1 |
| 29 | 3 | East Lake Sammamish | 1000.4 | 10.3 | 0.4 | 0.2 | 1187.7 | 12.2 | 0.8 | 0.3 | 1461.0 | 15.1 | 0.8 | 0.3 | 1561.6 | 16.1 | 0.7 | 0.2 |
| 30 | 3 | East Lake Washington | 4072.8 | 30.3 | | | 4122.9 | 30.7 | | | 4170.3 | 31.0 | | | 4200.0 | 31.3 | | |
| 31 | 3 | Forbes | 706.8 | 30.4 | | | 712.6 | 30.6 | | | 719.9 | 30.9 | | | 732.0 | 31.5 | | |
| 32 | 3 | Green Lake | 3768.4 | 44.7 | | | 3771.8 | 44.8 | | | 3773.4 | 44.8 | | | 3776.7 | 44.8 | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | 3 | Juanita | 1501.3 | 35.8 | | | 1515.2 | 36.2 | | | 1526.5 | 36.4 | | | 1537.5 | 36.7 | | |
| 34 | 3 | Lower Swamp | 2512.1 | 31.1 | | | 2590.9 | 32.1 | | | 2635.7 | 32.6 | | | 2743.9 | 34.0 | | |
| 35 | 3 | Lyons | 779.0 | 29.1 | | | 779.2 | 29.1 | | | 780.0 | 29.2 | | | 789.2 | 29.5 | | |
| 36 | 3 | May | 722.5 | 18.4 | 248.5 | 4.9 | 773.6 | 19.7 | 251.5 | 5.0 | 857.0 | 21.8 | 268.2 | 5.3 | 912.7 | 23.3 | 273.7 | 5.4 |
| 37 | 3 | McAleer | 2078.1 | 39.3 | | | 2102.1 | 39.8 | | | 2146.8 | 40.6 | | | 2165.4 | 40.9 | | |
| 38 | 3 | McDonald | | | 125.9 | 3.9 | | | 130.8 | 4.0 | | | 134.7 | 4.1 | | | 135.9 | 4.2 |
| 39 | 3 | Mercer Island | 1042.4 | 25.7 | | | 1049.4 | 25.8 | | | 1049.4 | 25.8 | | | 1060.1 | 26.1 | | |
| 40 | 3 | Nearshore | 6188.1 | 28.7 | | | 6376.1 | 29.6 | | | 6518.4 | 30.2 | | | 6651.0 | 30.9 | | |
| 41 | 3 | North Lake Washington | 382.6 | 33.0 | | | 383.0 | 33.0 | | | 383.0 | 33.0 | | | 387.5 | 33.4 | | |
| 42 | 3 | Peterson | 29.3 | 4.9 | 108.4 | 3.1 | 39.5 | 6.6 | 109.2 | 3.1 | 63.9 | 10.7 | 117.2 | 3.3 | 82.0 | 13.7 | 122.0 | 3.5 |
| 43 | 3 | Thornton | 3016.0 | 41.7 | | | 3025.7 | 41.8 | | | 3025.7 | 41.8 | | | 3043.5 | 42.1 | | |
| 44 | 3 | Tibbetts | 300.3 | 15.2 | 1.7 | 0.1 | 344.8 | 17.4 | 1.7 | 0.1 | 344.8 | 17.4 | 1.7 | 0.1 | 406.0 | 20.5 | 1.6 | 0.1 |
| 45 | 3 | Upper Swamp | 2101.5 | 27.6 | | | 2226.2 | 29.3 | | | 2392.5 | 31.4 | | | 2593.0 | 34.1 | | |
| 46 | 3 | West Lake Sammamish | 2087.0 | 27.0 | 0.1 | 0.2 | 2202.8 | 28.5 | 0.1 | 0.2 | 2247.5 | 29.1 | 0.1 | 0.2 | 2256.6 | 29.2 | 0.1 | 0.3 |
| 47 | 3 | West Lake Washington | 4894.4 | 42.2 | | | 4931.0 | 42.5 | | | 4946.5 | 42.6 | | | 5007.0 | 43.1 | | |

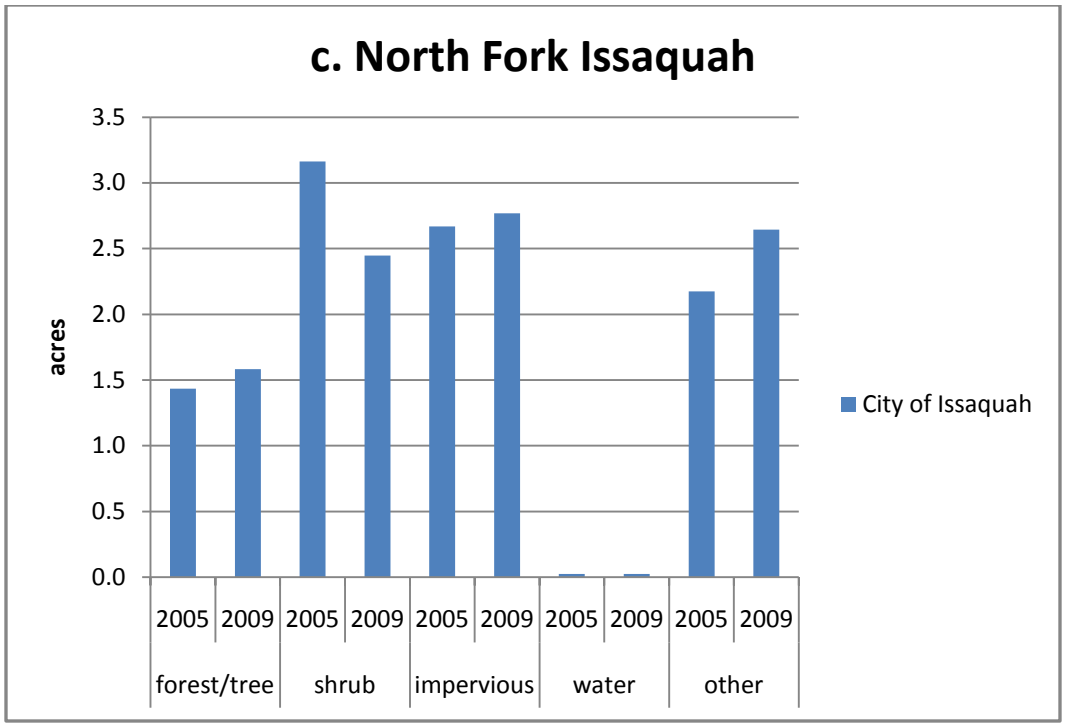
# Appendix D

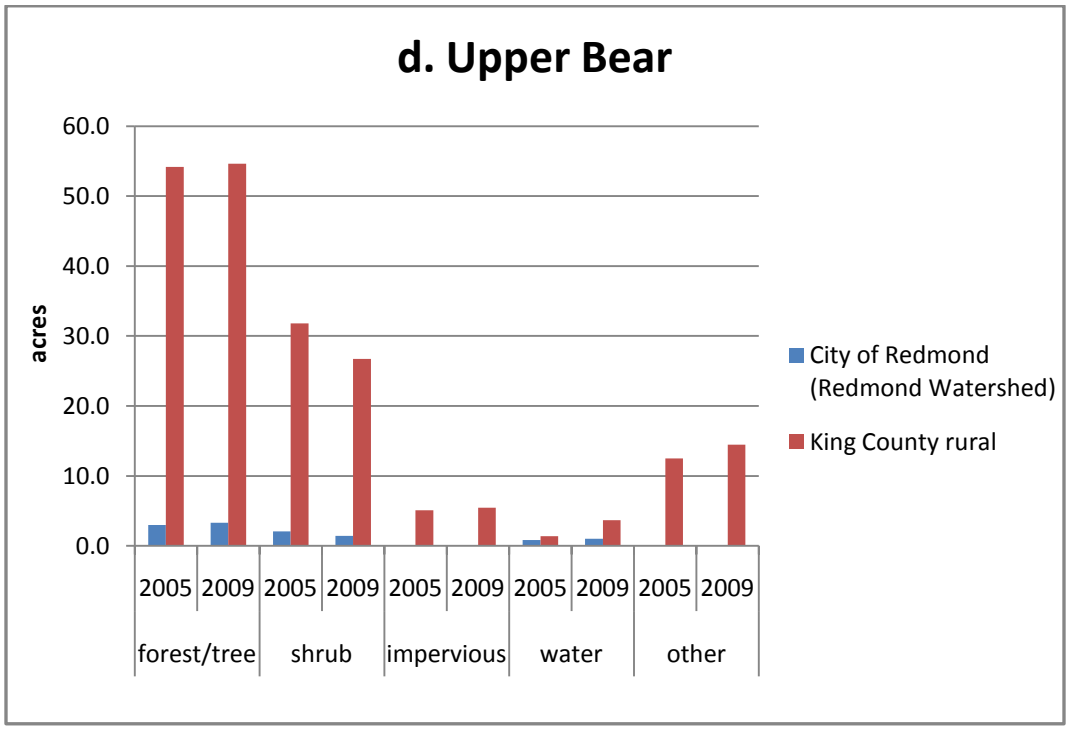
**Figure D1. Area in 2005 and 2009 in each of the five land cover classes.[12] Data are for each basin in the riparian area study, grouped by jurisdiction.**

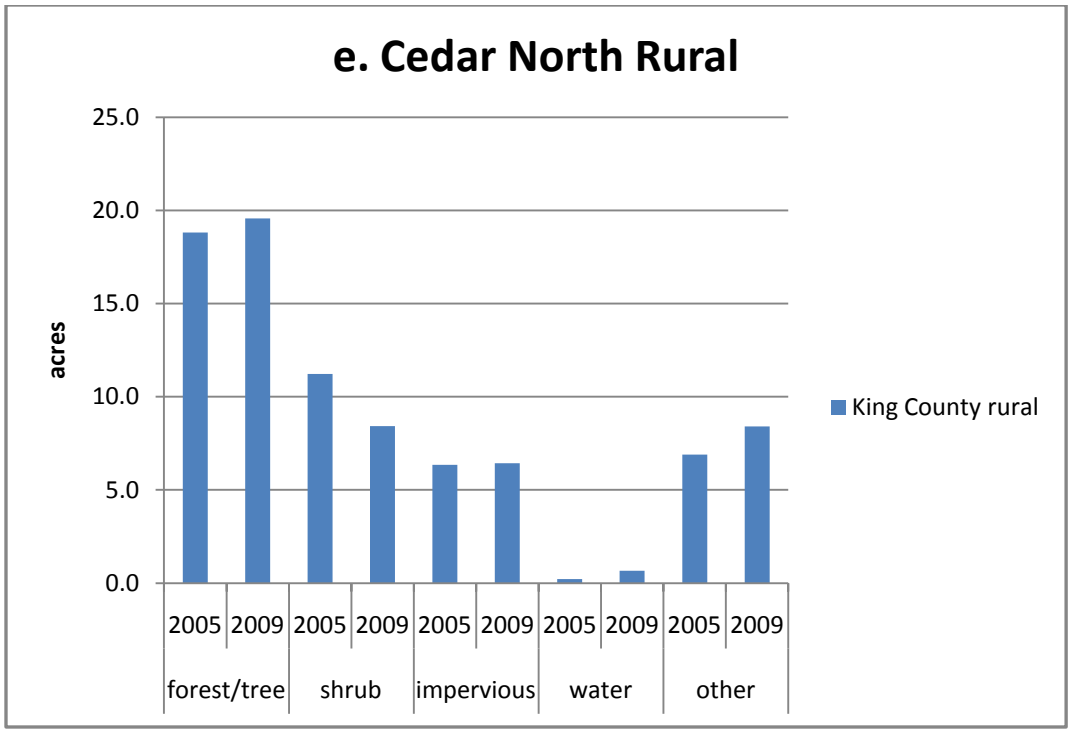


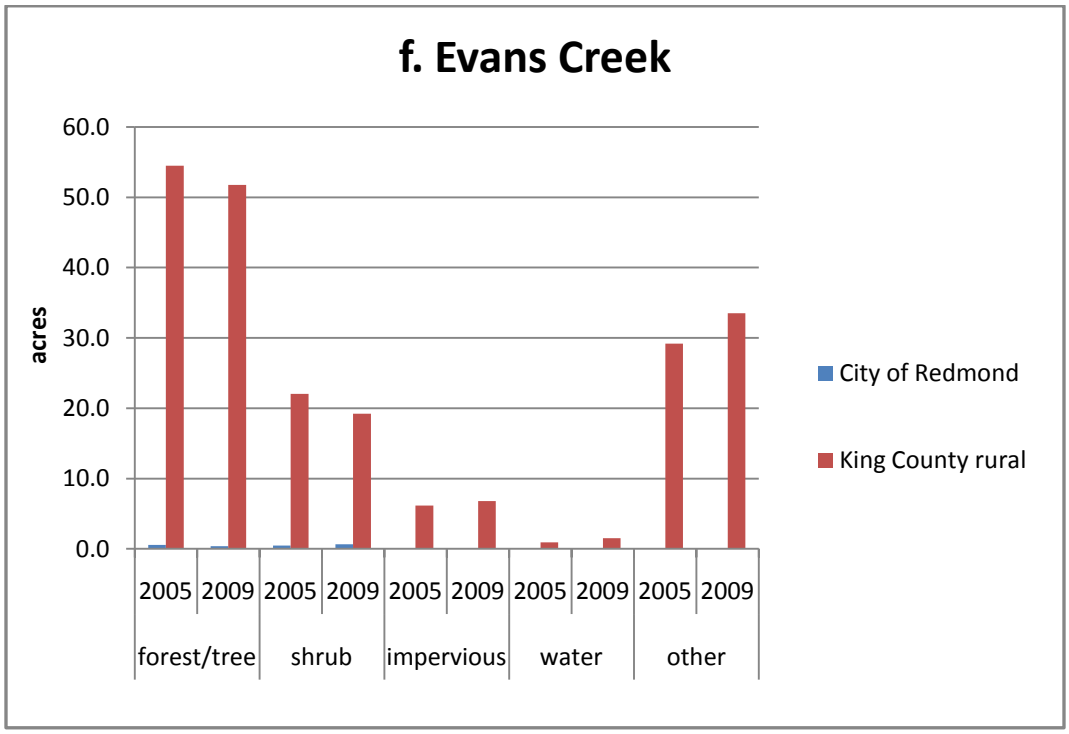



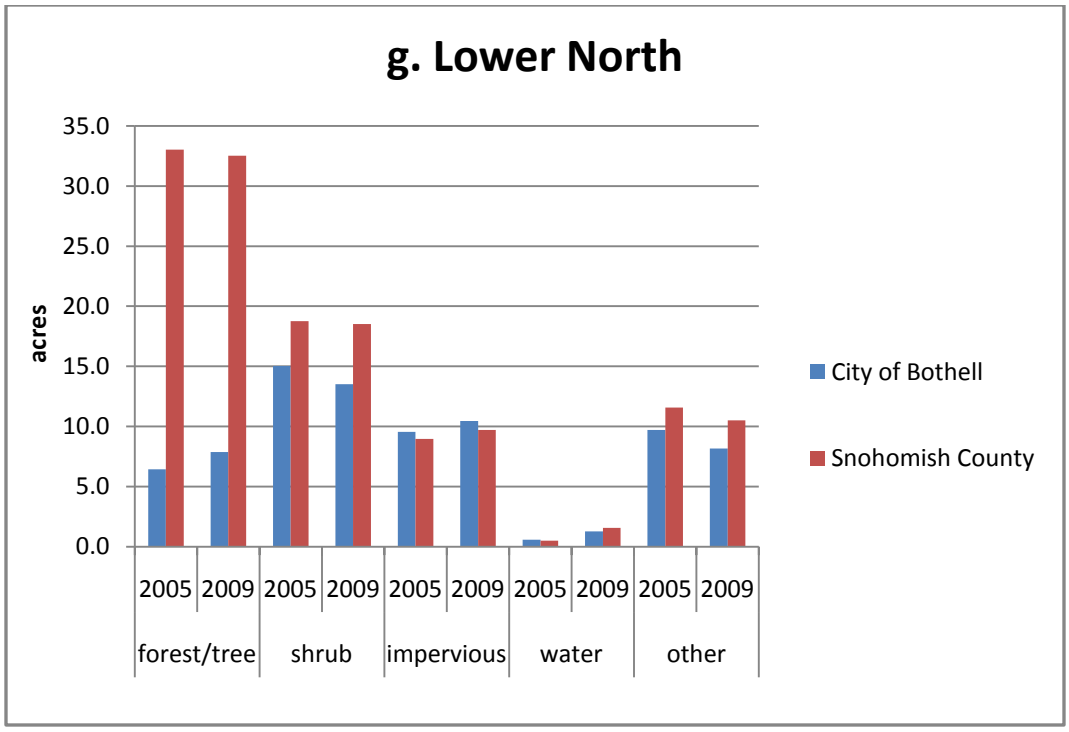

[12] "Other" includes all other non-impervious land cover types (grass, lawn, mud, reed canarygrass, gravel pit, etc.). For additional information on the cover classes, see section 2.3 and Table 13.

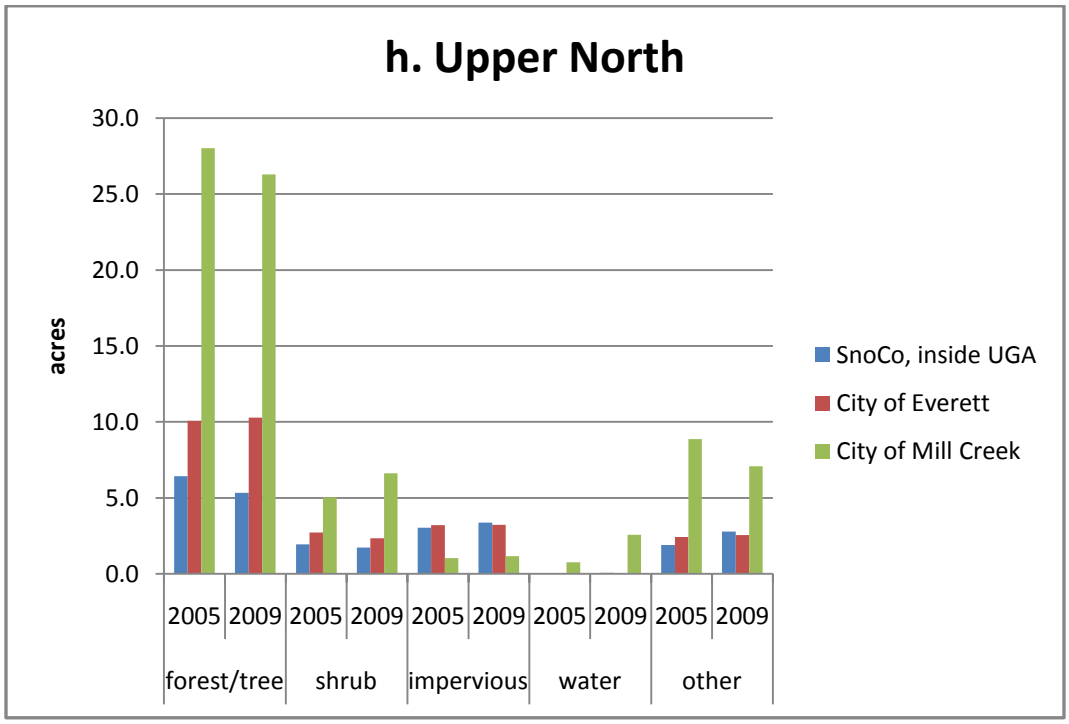

c. North Fork Issaquah
acres
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2005
2009
forest/tree
shrub
impervious
water
other
City of Issaquah


d. Upper Bear
acres
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2005
2009
forest/tree
shrub
impervious
water
other
City of Redmond (Redmond Watershed)
King County rural


e. Cedar North Rural
25.0
20.0
15.0
10.0
5.0
0.0
acres
2005
2009
forest/tree
shrub
impervious
water
other
King County rural


f. Evans Creek
60.0
50.0
40.0
30.0
20.0
10.0
0.0
acres
2005
2009
forest/tree
shrub
impervious
water
other
City of Redmond
King County rural


g. Lower North
acres
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2005
2009
forest/tree
shrub
impervious
water
other
City of Bothell
Snohomish County


h. Upper North
acres
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2005
2009
forest/tree
shrub
impervious
water
other
SnoCo, inside UGA
City of Everett
City of Mill Creek