Land Cover Model of Snohomish County Area from September 2006 Landsat 5 Imagery

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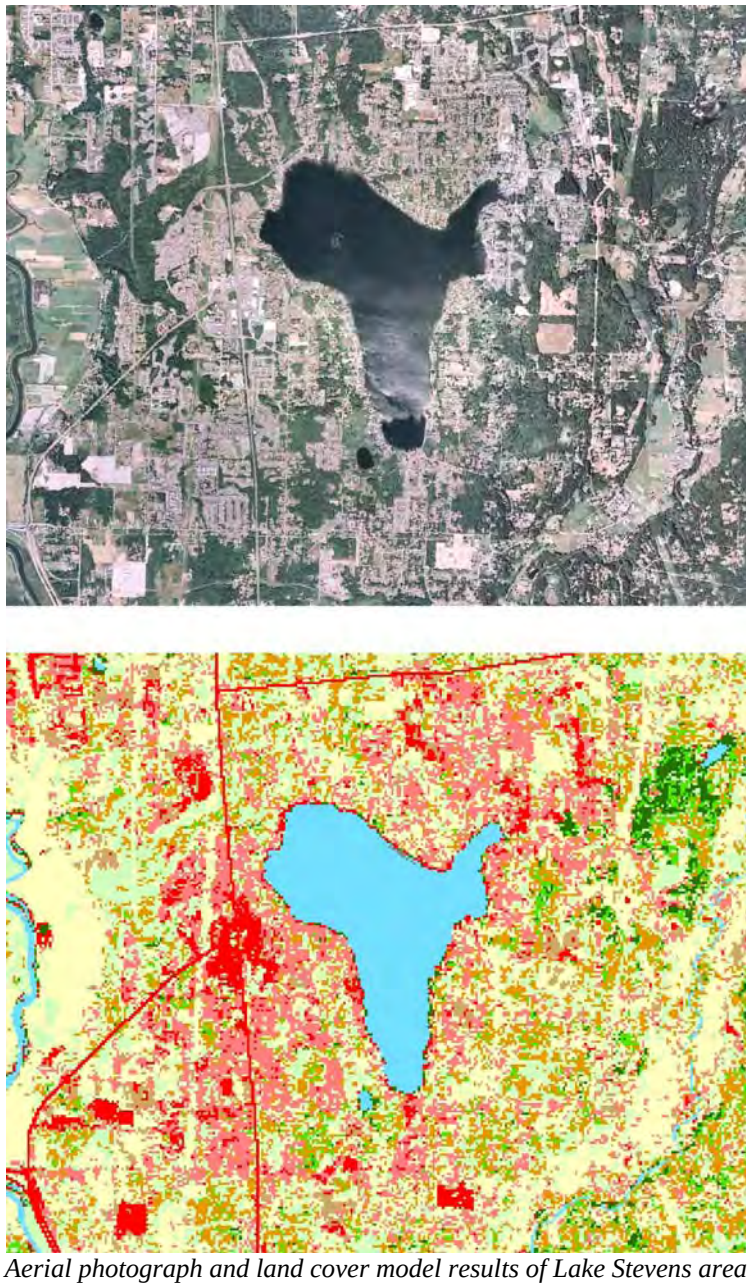

Aerial photograph and land cover model results of Lake Stevens area

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Introduction

Simmonds, et al. (2004) reported subbasin and nearstream land cover values[2] from a hybrid, unsupervised-supervised classification of 1991 Landsat 5 imagery and compared project area and watershed cover class percentages with results from a classification of August 2001 Landsat 7 imagery (Purser, et al., 2003) for the Snohomish and Stillaguamish watersheds. These values have been used to evaluate watershed hydrologic, riparian functional, and stream physical habitat conditions in Snohomish County. This report builds on that earlier work by reporting modeled land cover results for WRIAs 5 (Stillaguamish), 7 (Snohomish), and portions of WRIAs 3, 4, and 8 classified from September 2006 Landsat 5 imagery.

Methods

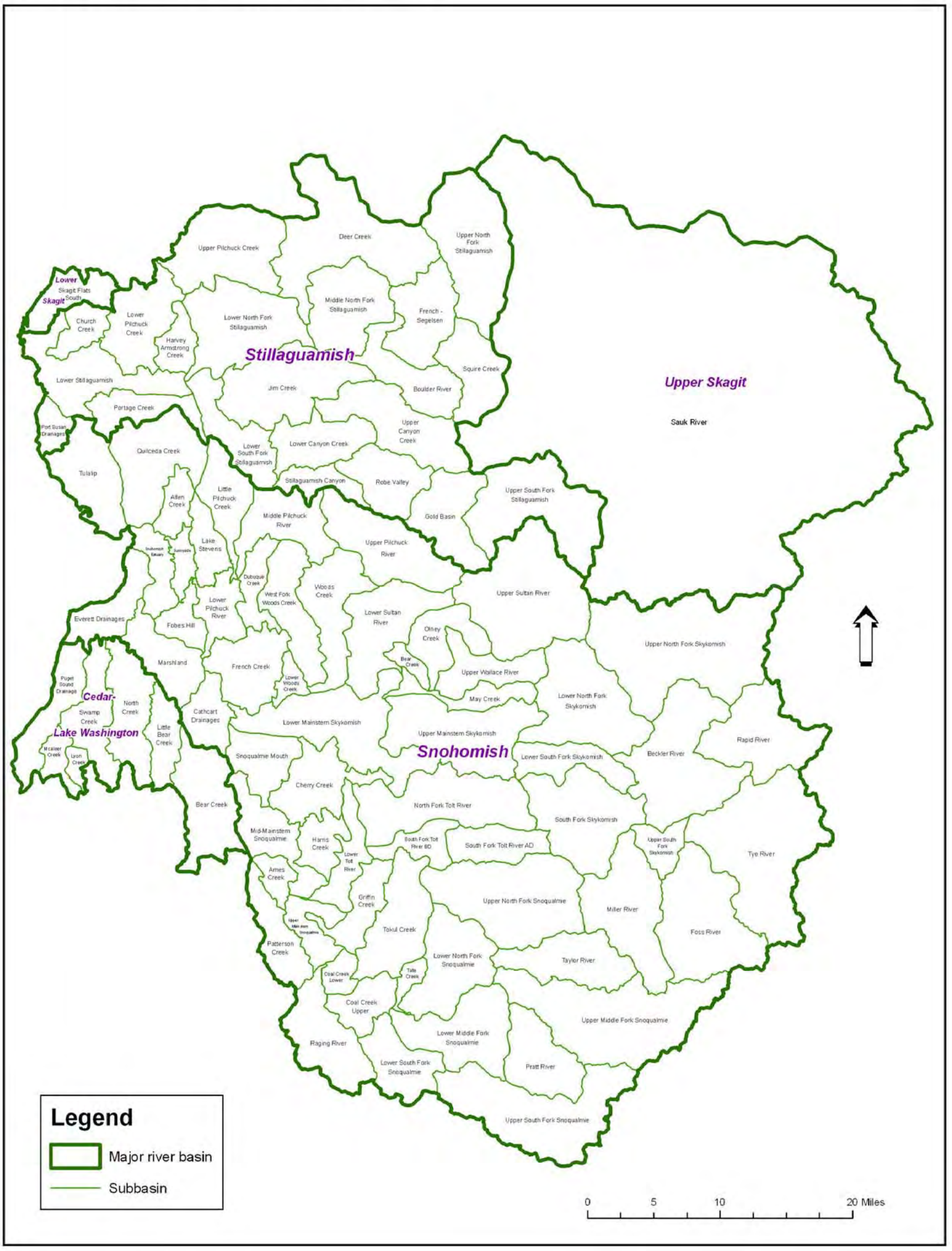
The methods used in the analysis of the September 2006 Landsat 5 images build on those used in analysis of two previous images from scenes captured in 2001 and 1991 (Purser, et al., 2003; Simmonds, et al., 2004). Two Landsat scenes that cover the project area (Fig. 1) were mosaicked, georeferenced, and an atmospheric correction algorithm was applied.

A sampling grid was applied (pixilation into 30 meter by 30 meter cells) and a 60-class unsupervised classification was run using ERDAS Imagine™. The classification was then supervised using 2006 digital orthophotography and Mt. Baker-Snoqualmie National Forest "stand year of origin" data[3]. The sixty classes were reduced to those fitting unambiguously into the 11-class classification scheme used previously (Table 1) and remaining "confused" (heterogeneous) classes . Additional unsupervised classification plus the use of ancillary data such as waterbody and major roads GIS data, elevation and slope classes, and differential Lidar[4] data was used to unconfuse the remaining classes.[5]

New or revised techniques and analysis done for the 2006 Land Cover Classification include:
Elevation - The USGS Digital Elevation Model was divided into three elevation bands: 0 – 700', 700' – 2500', and above 2500'. With the 1991 and 2001 land cover analyses only two bands of elevation was used. For this classification pixel values of impervious surfaces were further separated into naturally occurring impervious and constructed impervious surfaces depending on which elevation zone they overly. For example, pixels in the lowest elevation zone were classified as high density development while those in the highest elevation zone were classified

[2] Percentage of subbasin area in cover class
[3] These data were reported in 1995. The inventory effort had taken years; cover changes occurred (e.g., timber was harvested) without updating of stand ages in some cases. Digital orthophotography provided back up "data" for these areas.
[4] Light Imaging Distance and Ranging
[5] It is not known whether this issue would be resolved if one simply requested 80 or 85 unsupervised classes to begin with. There is value in selecting the fewest number of classes to begin with in order to see patterns in the resulting grid and relate them to landscape patterns evident in the digital orthophotography. Requesting 155 or 255 unsupervised classes is seen as an unrewarding exercise for our purpose. The resulting grid is patternless and there are few means available to locate oneself on the grid, much less find consistencies with a named cover class evident from digital orthophotography.

Figure 1 *Subbasins*



as alpine rock / talus slope. This technique was further used to separate bare ground (clear cuts, cultivated fields) from talus slope.
Rivers - River polygons were converted to pixels and overlaid with the land cover. This was done to bolster the open water class and better separate the gravel bar from the water. Because the satellite imagery is captured in low flow conditions the gravel bar is predominant.

Highway - Highway vectors were converted to pixels and overlaid with the land cover. This was done to improve the mapping of high density development; particularly where highways cross major water bodies.

Wetlands - Wetland features mapped in the County water body layer were classified as shrub. These areas are generally in the floodplains of large rivers.

Vegetation Heights- For some areas within the County vegetation height was used in mapping forest classes. This was accomplished by subtracting the LiDAR-derived bare earth surface model from first return model. The resulting layer was used to map tree heights, and provided an excellent tool for distinguishing forest age classes.

After supervising the classification of the confused classes, an accuracy assessment was run. This assessment compared the modeled or predicted land cover of 20 randomly selected 5 pixel by 5 pixel blocks of each class with actual land cover from 2006 orthophotos. The photography was viewed at a scale of between 1:6000 and 1:3000 and a determination was made as to whether the predicted class (the class modeled by the classification exercise) matched the actual class.

Class percentages were calculated for each subbasin in the project area. Subbasins are generally natural watersheds between 5000 and 50000 acres that drain to larger streams or the nearshore. Since nearstream areas are an important focus for salmon conservation planning and analysis, native plant restoration, hydrologic and hydraulic modeling, and capital project development, a second set of land cover values was calculated for each watershed. This set of values represents the modeled land cover which lies within three pixels on both sides of a Snohomish County watercourse layer derived and updated from Washington State Department of Natural Resources (WADNR) GIS layers of stream Types 1, 2, and 3 (fish-bearing streams). Watershed and nearstream land cover class values were derived using ArcGIS™ raster modeling capabilities (GRID).

In many cases, because of historical land use and development patterns, nearstream values can be significantly different than those for the whole watershed. A comparison is made of subbasin and nearstream land cover class values within the same subbasin. Further, people are often interested in how land cover varies by land use and/or ownership. To that end we have summarized land cover for Urban Growth Areas (incorporated, unincorporated, and total), Agriculture, Rural and Forestry (Federal, State, and private) land uses. Finally, cover class values are also presented by basin or WRIA in order to quantitatively compare differences in land cover over these larger geographic areas.

Table 1. Land Cover Classes

Eleven classes (ten land cover classes plus an "Unknown" class) resulted from the above analysis. The classes, what digital orthophotography shows they are actually composed of, and their preliminary interpretation for ecological, hydrological and hydraulic purposes are:

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.

5- Grass: Contains lawns and fields, agricultural crops, meadow, marsh, wetland; recent clearcuts.

6- Bare Ground: Consists of bare soil in agricultural, rural, and urban areas; also gravel pits, and recent clear cuts.

7- Medium density development: Consists predominately of urban and suburban residential areas; contains roads, driveways, and sidewalks; roofs, lawns, landscaping, and limited amounts of bare ground.

8- High density development: Consists of urban multifamily residential, commercial, and industrial; roads, roofs, and parking lots. Limited areas of bare ground and sand/gravel bars also show up as this class.

9- Alpine Rock/Talus Slopes: Consists predominately of high elevation exposed bedrock and talus slopes.

10- Open water: Lake, large river, reservoir.

11- Unknown: Shadow, cloud.

Results

Figure 2 displays the modeled land cover of September 2006. Table 2 shows the number of pixels and % of total that are classified in each class in the project area in 2006. The numbers reflect the modeled land cover of WRIAs 5 and 7, and the aforementioned part of WRIA 8. Table 3 displays the results of the accuracy assessment.

Table 2. 2006 Land Cover Cell Count per Class

Pixels	Land Cover Class	% of Total[6]
2,664,302	Mature evergreen forest	22%
2,092,701	Medium evergreen forest	18%
1,248,175	Deciduous stands	10%
2,890,188	Shrub / small trees	24%
1,488,705	Grass	12%
184,949	Bare ground	2%
298,777	Medium density development	3%
173,213	High density development	1%
648,168	Alpine rock / talus slope	5%
142,781	Open water	1%

2006 land cover class values are in Appendix A. Table A-1 is subbasin land cover (WRIAs 5,7 and the Snohomish County portion of WRIA 8); Table A-2 is a summary of calculated subbasin values for total forest, mature evergreen forest, and total impervious area[7] for these same subbasins; Table A-3 is the nearstream land cover and Table A-4 is a summary of calculated nearstream values for total forest, mature evergreen forest, and total impervious area. Table A-5 is the subbasin land cover broken down by broad land use class. Summary values are adjusted for Unknown, Open Water, and Alpine Rock/Talus Slope classes. Thus the adjusted summary values for mature forest, total forest, and impervious area are relative to the amount of area that could be forest, the natural vegetation in most of Snohomish County[8].

[6] The values are the percent of total cells, but not including Unknown. There were 87,764 cells of Unknown; much less than 1%. Percentages do not necessarily sum to 100 due to rounding.

[7] % Total Impervious Area (TIA) = 0.9(%High Density Development) + 0.45(%Medium Density Development) Purser, et al., 2003)

[8] For example, Adjust Total Forest Cover = ((MatEvFor+MedEvFor+0.55DecidStands)*100)/(100-Unknown-OpenWat-ARTS)

Figure 2

Land Cover 2006

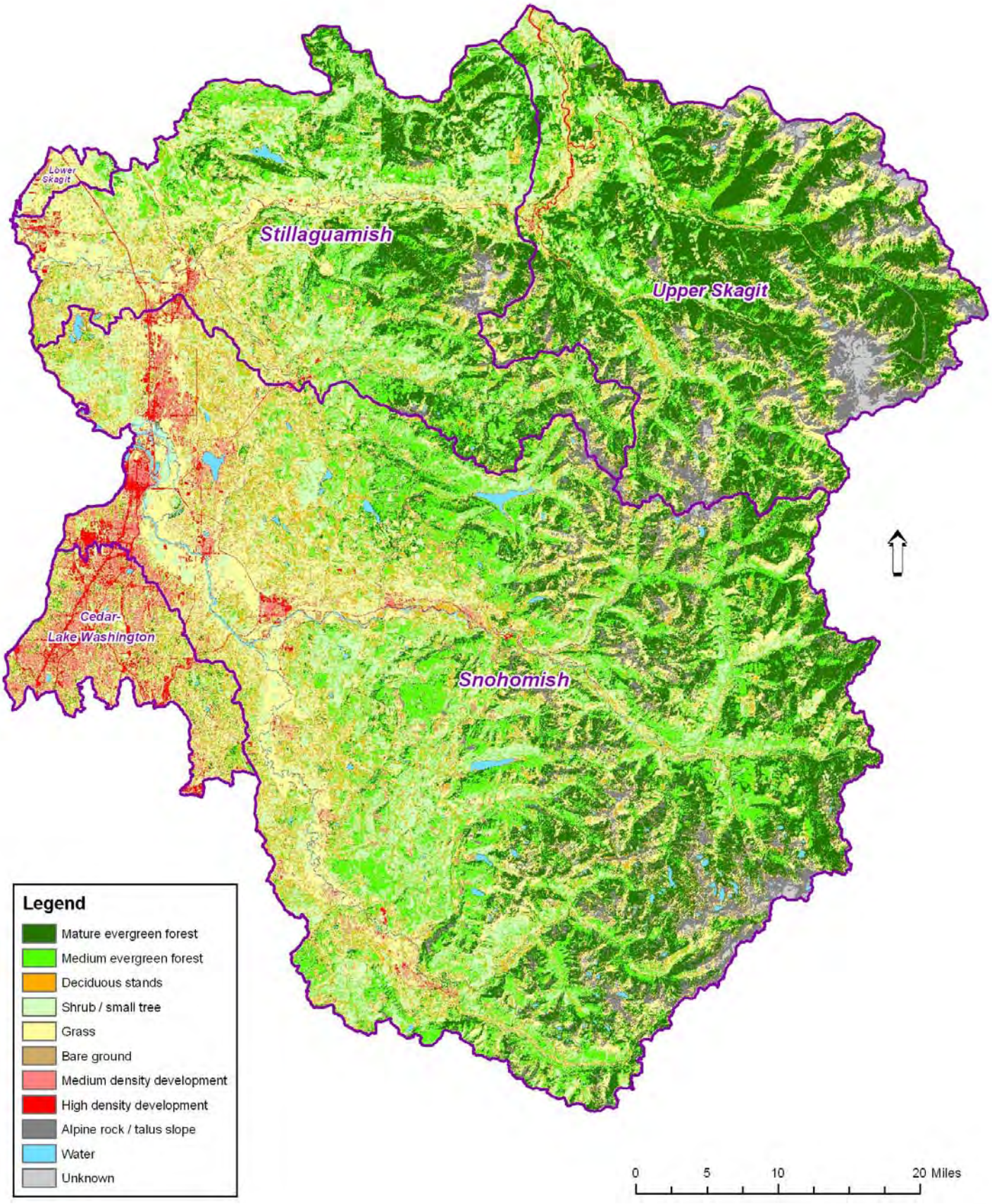


Table 3. Error Matrix for 2006 classified land cover

Error Matrix for 2006 Land Cover Classification

			Actual Cover Class											Classified
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**Correctly (%)**
Predicted Cover Class	**1**	Mature Forest	19										19	100.0%
	2	Med. Evergreen Forest		20									20	100.0%
	3	Deciduous Forest			11	9							20	55.0%
	4	Shrub\Small Tree			3	16	1						20	80.0%
	5	Grass					20						20	100.0%
	6	Bare Ground						19					19	100.0%
	7	Med. Density Development					2		17				19	89.5%
	8	High Density Development						3		16			19	84.2%
	9	Alpine Rock		2			1				17		20	85.0%
	10	Open Water										20	20	100.0%
		Total	19	22	14	25	24	22	17	16	17	20	196	**89.3%**

Discussion

Results obtained by modeling land cover using a hybrid unsupervised-supervised method can be examined in several ways useful to planning, regulatory, and science functions. Below is discussed the accuracy assessment results, numerical and spatial distribution of the different cover classes and resulting summary values, and an evaluation of summary land cover values compared to regional criteria[9].

Accuracy Assessment

The accuracy assessment (Table 3) shows the number and percentage of correctly identified blocks from the random sampling of all possible blocks in each cover class. The overall accuracy, 89.3% (175/196), is acceptable for potential uses of the data. The least accurate class is Deciduous Stands (55%). Without this class in the accuracy assessment the overall accuracy would be 93.2% (164/176). Although the reported accuracy of Deciduous Stands for 2001 land cover was 100% (5 of 5), the accuracy of the 1991 Deciduous Stands was also the lowest of the classes and was also 55%.

Classification of 2001 Deciduous Stands was made easier and more accurate by the "leaf off" timing of the digital orthophotography (March 2001) used for the supervised classification[10]. The quality (clarity, contrast, resolution) of the photography used in the classification of 2001 land cover (1998 WADNR and 2001 Snohomish County PUD) was significantly better than the 1990 (Puget Sound Regional Council) photography used for supervising the classification of 1991 land cover. In addition, since most shrubs are deciduous, many small trees are coniferous, and these cover types commingle across the landscape, the Deciduous Stands and Shrubs and Small Trees are the most difficult to classify with high accuracy.

A final note is the continuing resemblance of High Density Development and Bare Ground. Bare Ground is a very accurate classification (100% in 2006 accuracy assessment), while some 15% of High Density Development was found to be bare ground (usually agriculture). Classification of some bare ground areas is affected by the gray color of most subsoils in the project area, bare soil in agricultural and developing areas, gravel pits, and other areas where the topsoil is removed; it can appear to be pavement (Medium or High Density Development) to Landsat.

It should be noted here that the accuracy assessment was applied randomly across the project area. This means that the accuracy results also apply to the nearstream land cover; a separate assessment was not performed. The minimum size of the blocks used in the accuracy assessment, 5 by 5, is smaller than the dimension of the nearstream area which is approximately 6 pixels wide by the length of Types 1-3 streams (WRIAs 5, 7 and the Snohomish County portion of WRIA 8). Thus the area under consideration is larger than the block size used to assess accuracy throughout the project area.

[9] NMFS (1996) and Spence, et al. (1996).
[10] Most, if not all, of digital orthophotography at Snohomish County is from summer, or "leaf on," months.

Project Area Land Cover Changes

2006 represents the first dataset we have analyzed in which Mature Evergreen Forest (MEF) is not the most numerous class (Table 4). MEF has been declining since 1991 while the Shrubs and Small Trees cover class has been growing (Simmonds, et al., 2004). Shrubs and Small Trees is now the most numerous cover class in the project area. As seen in Table 5 below, federal forestlands is the only land use category that has more Mature Evergreen Forest than the project area "average." These forestlands are thus anchoring the project area with regard to the provision of watershed conditions necessary for the provision of high quality aquatic habitat. The private and state forestlands and rural land use categories all have about one-third or more of their area in Shrubs and Small Trees.

Table 4. Class Abundance 1991, 2001, 2006

	Cell Count		
Cover Class	**1991**	**2001**	**2006**
Mature evergreen forest	3,550,519	3,035,608	2,664,302
Medium evergreen forest	1,647,850	2,346,238	2,092,701
Deciduous stands	1,414,740	1,070,914	1,248,175
Shrub / small trees	2,295,625	2,572,399	2,890,188
Grass	1,340,547	878,392	1,488,705
Bare ground	416,791	607,377	184,949
Medium density development	182,642	276,698	298,777
High density development	140,359	191,255	173,213
Alpine rock / talus slope	589,574	528,718	648,168
Open water	143,905	150,641	142,781
Unknown	198,682	263,537	87,764
Total	11,923,225	11,923,778	11,921,729

Interbasin Differences in Cover Class and Summary Values

WRIA 5, WRIA 7 and the Snohomish County portion of WRIA 8 display different land cover characteristics. This is to be expected due to different land use history and current land use designations, and innate topographic, geomorphic, and ecological characteristics. Table 5 displays summary values and selected cover class values for the different basins and for the project are as a whole.

Table 5. 2006 Basin Summary and Selected Cover Class Values Compared to Project Area Values

Area	Adjusted Mature Evergreen Forest (%)	Adjusted Total Forest (%)	Adjusted Total Impervious Area (%)	Shrubs and Small Trees (%)	Grass Plus Bare Ground (%)
WRIA 5	21.44	48.19	1.2	29.11	14
WRIA 7	20.11	46.8	2.0	26.8	14.35
WRIA 8 (partial)	3.71	16.4	20.7	17.3	24.4
Project Area	22	47.9	2.39	24	14

Table 5 displays little difference between WRIA's 5 and 7. WRIA 7 displays a bit more impervious area, but it is suspected that while there is likely more impervious in WRIA 7, the decimal places above appear more precise than they are. The main difference, and also the one that would be expected is that between WRIA 8 portion of Snohomish County and the rest of Snohomish County. While one could argue that the WRIA-level impervious area of WRIA's 5 and 7 are not significantly affecting fish habitat, WRIA 8 impervious area value lands on the far side of the "not properly functioning" line (Table 7 below). The amount of impervious area in certain individual subbasins throughout the project area is likely to have a major effect on fish habitat (Tables 9).

Land Cover by Land Use

As might be expected, land cover varies significantly across the broad land use categories used in Table 6[11]. In general, forest cover increases across the agriculture (least forest)/urban/rural/forest land use spectrum, while impervious area decreases across the urban/agriculture/rural/forest land use spectrum. Among the forestland subcategories, total forest cover is highest on federal forestlands (68%) and ranges down to 43.5% on private forestlands. Rural land uses have less than 25% of their area in forest; UGA's have about 10% in forest and agriculture has the least forest at a little over 6%. Mature Evergreen Forest follows the same general pattern, however, the differences in coverage by this class are more significant among the forestland subcategories. All other land use categories have 3% or less forest that is 100 years old or older.

As would be expected impervious area is highest in the UGA's. Forestlands have little to no impervious area (as viewed from a satellite) and rural areas have about 3.6%. The somewhat higher value of impervious area in agricultural land use areas is likely inflated due to the misclassification of some bare soil as development due to the similar reflectance of exposed subsoil material in agricultural areas and concrete. Further, it is also likely due to the similarity of gravel bars and bank revetment in agricultural or rural areas, such as the Sauk River area, to concrete. We attempted to minimize this influence by overlaying a waterbody GIS layer on the

[11] Categories are derived from Future Land Use designations in 2006 Snohomish County Comprehensive Plan and therefore the data are from lands within Snohomish County only.

Table 6. Summary and Selected Cover Class Values by Broad Land Use Categories

Area	Adjusted Mature Evergreen Forest (%)	Adjusted Total Forest (%)	Adjusted Total Impervious Area (%)	Shrubs and Small Trees (%)	Grass Plus Bare Ground (%)
Unincorporated Urban Growth Area	2.1	11.4	22.7	17	27
Incorporated Urban Growth Area	2.0	8.6	29.4	14	26
Total UGA	**2**	**9.6**	**27**	**15**	**26**
Rural	3	22.3	3.6	35	28
Agriculture	1.1	6.2	5.3	24	54
Federal Forestlands	43.2	68	0	15	8
State Forestlands	17.5	53.7	0	32	8
Private Forestlands	10.2	43.5	0	40	9
Total Forestlands	**34.6**	**62.5**	**0**	**21**	**8**
Project Area	**23.4**	**47.9**	**2.39**	**24**	**14**

classification to classify as much as possible as Open Water. Hydrologically, Open Water, gravel bars, revetment, and other water and rock surfaces that drain directly to surface water are impervious, however, response to earlier reports indicated that this is confusing and counter-intuitive to many users of these modeled results. Therefore we have tried to minimize both the confusion and the classification of non-built surfaces as impervious area.

The Shrubs and Small Trees class is greatest in the private forestlands, then rural and then state forestlands. All these land use categories have about a third or more in this cover class. About 24% of the agriculture land use area is in Shrubs and Small Trees; some of these areas are hybrid poplar plantations while others are along streams and rivers. Fourteen to 17% of the area in UGA's and also federal forestland is in this class as well. Some areas of this class are in

transition in regenerating forests. This class, as well as the Grass and Bare Ground classes, is hydrologically immature. Thus even on state and private forestlands, 40-50% of the area is hydrologically immature and is likely contributing to higher peak flows and longer stormflow periods in subbasins dominated with these land uses.

Overall, 24% of the entire project area is in the Grass or Bare Ground classes. This is similar to the Rural and UGA areas (26, 27, and 28%). Agricultural areas have twice this level of Grass plus Bare Ground during the September timeframe during which the Landsat images were captured. All forest subcategories had less than 10% of this combination of disturbed land cover.

Within the Urban Growth Area subcategories, incorporated areas have a little less forest, fewer Shrubs and Small Trees, and about 33% more impervious area than unincorporated areas. Of course, these unincorporated areas will likely be incorporated in the near future and thus we will likely see a reduction in trees and shrubs around existing cities and a further increase (over their previous states as agricultural or rural lands) in impervious area.

There is a relatively dramatic range of land cover in the different forest land use subcategories. As noted above, federal forest have more than 50% more forest cover than private forestlands; state forestlands fall in the middle. Federal forestlands have 400% as much forest that is 100 years old or older than private forestlands and more than 200% the amount that state forestlands have. Clearly the burden of providing sufficient forest cover to support high quality aquatic habitat is being borne by the federal forests within Snohomish County. All the subcategories have no measurable impervious area and less than 10% Grass plus Bare Ground.

It should be noted as a prelude to the following section that Federal forestland is the only land use category that has the characteristics thought to be able to support native aquatic life. State and private forestlands, though they have no measurable impervious area, have 40-50% hydrologically immature vegetation (or bare ground) and thus are delivering storm water at rates far in excess above those at which large wood, overhanging banks, and suitable sediment levels can be maintained (Booth, Hartley, and Jackson, 2002; May et al., 1997).

Evaluation of 2006 Land Cover

NMFS (1996) and Spence, et al. (1996) proposed or compiled watershed and waterbody characteristics thought to be the minimum or maximum values needed to maintain or restore aquatic habitat for Endangered Species Act-listed species. Booth, Hartley and Jackson (2002) further clarified levels of hydrologically mature forest (our Adjusted Total Forest Cover) needed when impervious area is low to non-existent. These values have been used to help evaluate watershed and riparian conditions and are found in Table 7. This should not be construed to be the only way to evaluate these conditions, but managers and others may find this useful.

Forest Land Cover

Table 8 displays mature and total forest cover in subbasins and nearstream areas within subbasins. The majority of the number of subbasins do not provide watershed or riparian forest characteristics to support a suitable aquatic habitat environment.

Table 7. Regional Land Cover Criteria

Variable/ Parameter	Properly Functioning	At Risk	Not Properly Functioning
Mature Evergreen Forest	>15%	>15%[12]	<15%
Total Forest	>80%	65-80%	<65%
Total Impervious Area	<7%	7-12%	>12%

Many subbasins have similar amounts of forest and mature forest at both the subbasin and riparian scales. Little Bear Creek, Woods Creek, Raging River, Marshland, Church Creek, Deer Creek, Harvey Armstrong, and Middle Pilchuck are examples of these subbasins. Other subbasins have more forest in the subbasin as a whole (including the riparian area) than in the riparian area alone. Sauk River, Boulder River, French-Segelsen, Middle North Fork Stillaguamish, Squire Creek, Upper and Lower North Fork Skykomish are examples of these subbasins. The subbasins are predominately in forestry land use areas, however, rural land uses are common on the floodplains of these subbasins. Thus, historical forestry practices and mixed land uses are both likely playing a role in the basin-specific characteristics.

Table 8. Subbasin and Nearstream Forest Cover

		Subbasin Scale		Riparian Scale	
WRIA	**SUBBASIN**	**Adjusted Total Forest**	**Adjusted Total Mature Evergreen Forest**	**Adjusted Total Forest Cover**	**Adjusted Mature Evergreen Forest**
3	Skagit Flats South	13	1	11	1
4	Sauk River	66	45	48	23
5	Boulder River	79	56	67	43
5	Church Creek	13	1	13	1
5	Deer Creek	62	34	61	34
5	French-Segelsen	55	29	34	15
5	Gold Basin	73	36	73	44
5	Harvey Armstrong Creek	30	7	29	5
5	Jim Creek	45	15	41	13
5	Lower Canyon Creek	37	8	43	11
5	Lower North Fork Stillaguamish	34	8	27	6

[12] The NMFS (1996) guidelines state that it is both the mature forest ("riparian reserves") and total forest that create a rating of function.

		Subbasin Scale		Riparian Scale	
WRIA	**SUBBASIN**	**Adjusted Total Forest**	**Adjusted Total Mature Evergreen Forest**	**Adjusted Total Forest Cover**	**Adjusted Mature Evergreen Forest**
5	Lower Pilchuck Creek	30	3	28	3
5	Lower South Fork Stillaguamish	23	4	26	7
5	Lower Stillaguamish	11	1	12	3
5	Middle North Fork Stillaguamish	46	17	33	11
5	Port Susan Drainages	28	4	36	13
5	Portage Creek	12	1	14	1
5	Robe Valley	51	19	51	20
5	Squire Creek	61	42	43	19
5	Stillaguamish Canyon	48	8	55	23
5	Upper Canyon Creek	67	32	66	32
5	Upper North Fork Stillaguamish	60	33	66	35
5	Upper Pilchuck Creek	48	14	48	14
5	Upper South Fork Stillaguamish	62	33	65	32
7	Allen Creek	8	1	8	1
7	Ames Creek	27	4	21	4
7	Bear Creek	34	3	40	4
7	Beckler River	62	32	54	28
7	Cathcart Drainages	18	2	17	3
7	Cherry Creek	36	5	37	7
7	Coal Creek_Lower	29	3	31	6
7	Coal Creek_Upper	32	3	29	4
7	Dubuque Creek	29	3	30	3
7	Everett Drainages	8	1	17	6
7	Fobes Hill	9	2	15	10
7	Foss River	69	42	73	54
7	French Creek	13	1	17	2
7	Griffin Creek	40	3	44	7
7	Harris Creek	34	4	35	6
7	Lake Stevens	15	1	17	3
7	Little Pilchuck	21	2	20	2
7	Lower Mainstem Skykomish	32	5	29	7
7	Lower Middle Fork Snoqualmie	44	15	43	13
7	Lower North Fork Skykomish	58	30	52	23

		Subbasin Scale		Riparian Scale	
WRIA	**SUBBASIN**	**Adjusted Total Forest**	**Adjusted Total Mature Evergreen Forest**	**Adjusted Total Forest Cover**	**Adjusted Mature Evergreen Forest**
7	Lower North Fork Snoqualmie	56	21	56	19
7	Lower Pilchuck	16	1	20	3
7	Lower South Fork Skykomish	57	27	54	24
7	Lower South Fork Snoqualmie	39	9	32	7
7	Lower Sultan River	53	17	56	25
7	Lower Tolt River	44	7	45	12
7	Lower Woods Creek	12	1	19	2
7	Marshland	7	1	6	2
7	May Creek	42	17	34	13
7	Middle Pilchuck	34	5	36	7
7	Mid-Mainstem Snoqualmie	20	2	20	6
7	Miller River	65	45	64	40
7	North Fork Tolt River	49	14	56	18
7	Olney Creek	62	19	55	21
7	Patterson Creek	22	1	25	2
7	Pratt River	69	37	70	39
7	Quilceda Creek	11	1	14	1
7	Raging River	39	5	39	7
7	Rapid River	71	50	n/a	n/a
7	Snohomish Estuary	6	2	10	6
7	Snoqualmie Mouth	17	2	17	6
7	South Fork Skykomish	55	26	45	18
7	South Fork Tolt River_Ad	56	19	63	13
7	South Fork Tolt River_Bd	42	8	44	10
7	Sunnyside	9	1	15	8
7	Tate Creek	42	3	40	3
7	Taylor River	62	39	66	42
7	Tokul Creek	38	4	43	7
7	Tulalip	23	2	25	5
7	Tye River	70	45	67	41
7	Upper Mainstem Skykomish	49	15	38	10
7	Upper Mainstem Snoqualmie	27	3	17	5
7	Upper Middle Fork Snoqualmie	62	40	68	42
7	Upper North Fork Skykomish	66	41	57	29

		Subbasin Scale		Riparian Scale	
WRIA	**SUBBASIN**	**Adjusted Total Forest**	**Adjusted Total Mature Evergreen Forest**	**Adjusted Total Forest Cover**	**Adjusted Mature Evergreen Forest**
7	Upper North Fork Snoqualmie	60	30	63	30
7	Upper Pilchuck	60	16	62	20
7	Upper South Fork Skykomish	65	31	51	27
7	Upper South Fork Snoqualmie	54	23	62	28
7	Upper Sultan River	55	26	50	19
7	Upper Wallace River	55	20	61	27
7	West Fork Woods Creek	28	2	28	3
7	Woods Creek	40	6	40	7
8	Bear Creek	27	6	26	6
8	Little Bear Creek	20	4	22	4
8	Lyon Creek	15	4	31	11
8	McAleer Creek	10	3	17	4
8	North Creek	11	2	15	2
8	Puget Sound Drainage	16	4	31	11
8	Swamp Creek	8	2	15	3

Finally, many urban and suburbanizing subbasins have greater amounts of forest and mature forest cover in the riparian area than in the subbasin as a whole. Puget Sound Drainages, Lyon Creek, Sunnyside, Fobes Hill, Snohomish Estuary, Everett Drainages, Port Susan Drainages, and Stillaguamish Canyon are examples of these subbasins. This is likely a result of historical avoidance of development of floodplain wetlands (for use other than agriculture), and possibly the effects of Critical Area Regulation implementation (1995 in Snohomish County).

Impervious Area

Table 9 displays a comparison between the amount of a subbasin that is impervious and the amount of the riparian area within that same subbasin that is impervious. In this case the high values are unsuitable for maintenance of conditions necessary for a high quality aquatic habitat environment. Most of the subbasins have less than seven per cent impervious at both scales.

Only seven subbasins have amounts of impervious area above 12% at both the subbasin scale and the riparian scale; five of these are in WRIA 8 (Everett Drainages and Allen Creek are the other two). There are a few subbasins that have significantly more impervious area at the subbasin scale than at the riparian scale (Lyon Creek, McAleer Creek, Swamp Creek, and Sunnyside). Port Susan Drainages and Lake Stevens are among the few subbasins that have more impervious area in the riparian part of the subbasin than at the scale of the whole subbasin.

Table 9. Subbasin v. Riparian Impervious Area

		Subbasin scale	Riparian scale
WRIA	**SUBBASIN**	**Adjusted Total Impervious Area (%)**	**Adjusted Total Impervious Area (%)**
3	Skagit Flats South	3.60	2.70
4	Sauk River	0.48	5.05
5	Port Susan Drainages	3.56	11.25
5	Lower Stillaguamish	6.55	9.09
5	Portage Creek	8.02	8.10
5	Lower South Fork Stillaguamish	3.53	7.27
5	Church Creek	4.95	3.15
5	Lower North Fork Stillaguamish	1.34	3.15
5	Middle North Fork Stillaguamish	0.89	3.15
5	Harvey Armstrong Creek	3.12	2.27
5	Stillaguamish Canyon	2.65	2.27
5	French-Segelsen	0.91	2.25
5	Lower Pilchuck Creek	1.34	1.35
5	Deer Creek	0.00	0.90
5	Boulder River	0.00	0.51
5	Jim Creek	0.45	0.45
5	Lower Canyon Creek	0.45	0.45
5	Squire Creek	0.49	0.00
5	Gold Basin	0.00	0.00
5	Robe Valley	0.00	0.00
5	Upper Canyon Creek	0.00	0.00
5	Upper North Fork Stillaguamish	0.00	0.00
5	Upper Pilchuck Creek	0.00	0.00
5	Upper South Fork Stillaguamish	0.00	0.00
7	Everett Drainages	36.70	33.28
7	Snohomish Estuary	6.15	19.72
7	Fobes Hill	11.14	17.44
7	Allen Creek	19.16	14.23
7	Lake Stevens	9.16	14.06
7	Quilceda Creek	14.40	10.35
7	Sunnyside	15.00	9.29
7	Marshland	14.56	8.35
7	Upper Mainstem Skykomish	2.30	7.42
7	Tulalip	2.12	6.85
7	May Creek	3.67	6.63
7	Lower Mainstem Skykomish	2.65	5.51

		Subbasin scale	Riparian scale
WRIA	**SUBBASIN**	**Adjusted Total Impervious Area (%)**	**Adjusted Total Impervious Area (%)**
7	Lower Pilchuck	6.24	4.95
7	Snoqualmie Mouth	1.76	4.64
7	Mid-Mainstem Snoqualmie	3.50	4.59
7	Lower Woods Creek	8.02	4.55
7	Coal Creek_Upper	3.12	4.55
7	Cathcart Drainages	5.19	4.26
7	Upper Mainstem Snoqualmie	2.18	4.13
7	Lower South Fork Snoqualmie	2.67	3.60
7	Coal Creek_Lower	2.62	3.21
7	French Creek	6.30	3.18
7	Lower South Fork Skykomish	0.98	2.93
7	Little Pilchuck	2.70	2.70
7	Lower Middle Fork Snoqualmie	0.46	2.30
7	Middle Pilchuck	2.21	2.27
7	Dubuque Creek	0.87	2.27
7	Lower North Fork Skykomish	0.00	1.89
7	Harris Creek	0.89	1.82
7	Lower Sultan River	0.44	1.39
7	Ames Creek	0.89	1.36
7	Lower Tolt River	0.45	1.36
7	Lower North Fork Snoqualmie	0.00	0.48
7	Upper North Fork Skykomish	0.49	0.48
7	Upper Wallace River	0.47	0.46
7	Bear Creek	0.45	0.45
7	Cherry Creek	0.45	0.45
7	Woods Creek	0.44	0.45
7	Olney Creek	0.00	0.45
7	Raging River	0.00	0.45
7	Upper South Fork Skykomish	0.00	0.45
7	Patterson Creek	2.25	0.45
7	West Fork Woods Creek	0.90	0.45
7	Griffin Creek	0.45	0.45
7	South Fork Tolt River_Bd	0.00	0.45
7	Foss River	0.54	0.00
7	Upper Middle Fork Snoqualmie	0.54	0.00
7	Miller River	0.52	0.00
7	Taylor River	0.49	0.00

		Subbasin scale	Riparian scale
WRIA	**SUBBASIN**	**Adjusted Total Impervious Area (%)**	**Adjusted Total Impervious Area (%)**
7	Beckler River	0.00	0.00
7	North Fork Tolt River	0.00	0.00
7	Pratt River	0.00	0.00
7	South Fork Skykomish	0.00	0.00
7	South Fork Tolt River_Ad	0.00	0.00
7	Tate Creek	0.00	0.00
7	Tokul Creek	0.00	0.00
7	Tye River	0.00	0.00
7	Upper North Fork Snoqualmie	0.00	0.00
7	Upper Pilchuck	0.00	0.00
7	Upper South Fork Snoqualmie	0.00	0.00
7	Upper Sultan River	0.00	0.00
7	Rapid River	0.00	n/a
8	McAleer Creek	33.09	22.27
8	Swamp Creek	31.05	20.45
8	North Creek	26.73	19.55
8	Puget Sound Drainage	22.28	17.42
8	Little Bear Creek	14.40	12.15
8	Lyon Creek	21.60	7.27
8	Bear Creek	7.57	6.89

Relationship Between Forest Cover and Impervious

Figures 3 (Subbasins) and 4 (Nearstream areas) display the relationship between forest cover values and impervious area values for individual subbasins. At a subbasin scale only one subbasin with more than 7% impervious has more than 20% forest cover. At the scale of the nearstream area within a subbasin only 3 subbasins with more than 7% impervious area have more than 20% forest cover. Thus, there appears to be a slight tendency for nearstream areas to retain forest cover a bit longer that watersheds as a whole during the urbanization process.

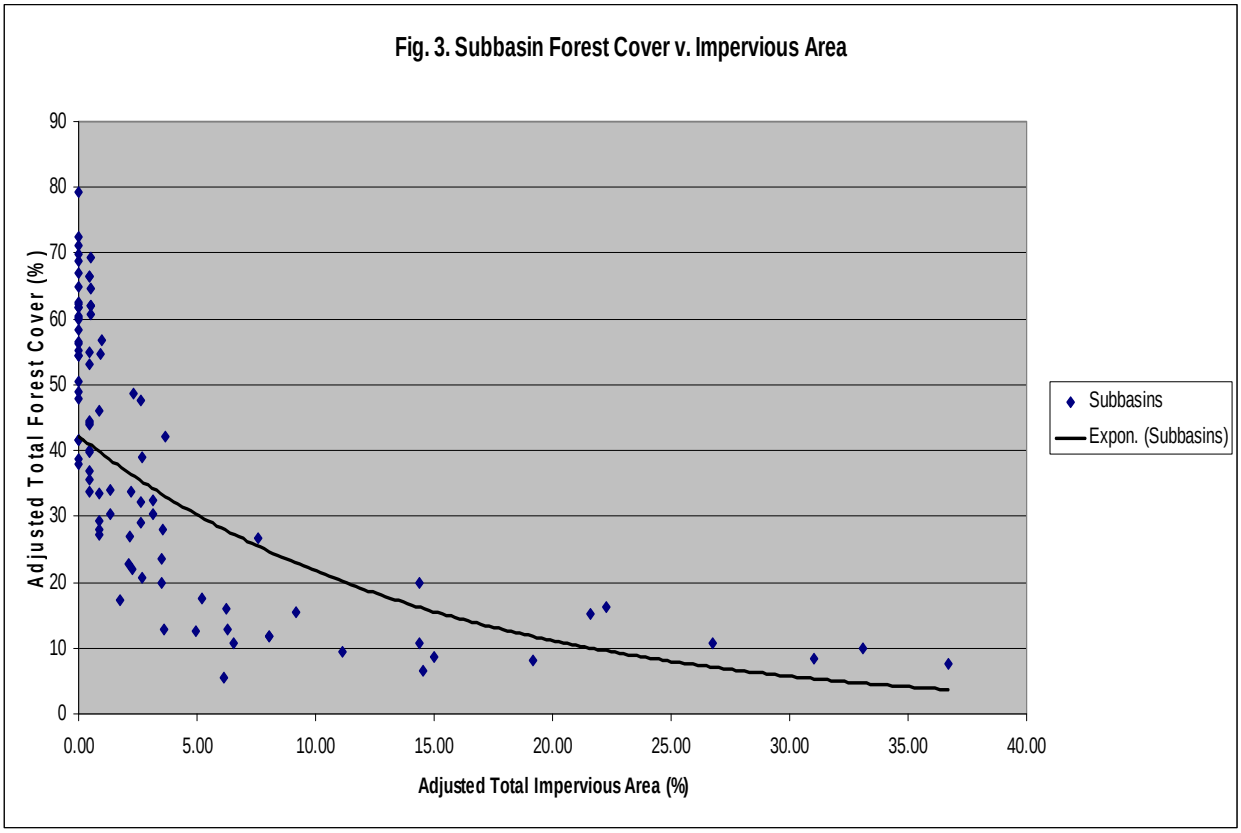


Fig. 3. Subbasin Forest Cover v. Impervious Area
Adjusted Total Forest Cover (%)
Adjusted Total Impervious Area (%)
Subbasins
Expon. (Subbasins)

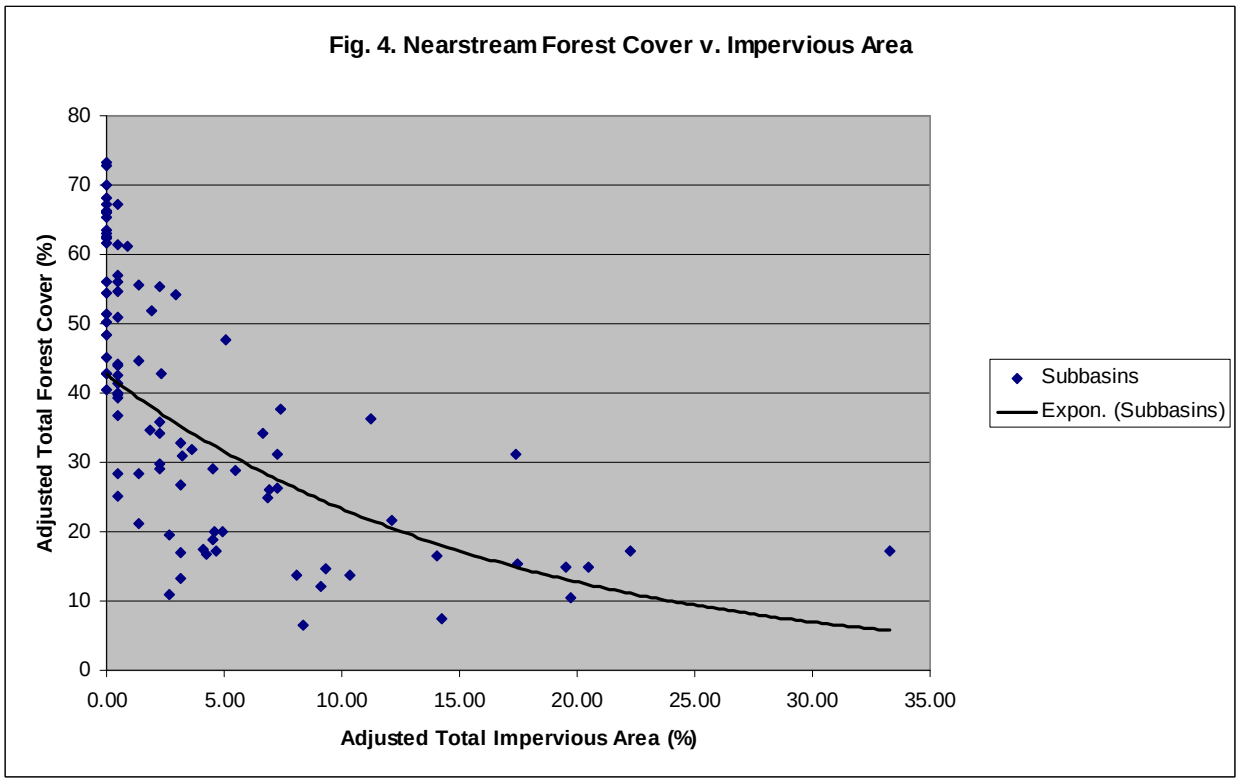


Fig. 4. Nearstream Forest Cover v. Impervious Area
Adjusted Total Forest Cover (%)
Adjusted Total Impervious Area (%)
Subbasins
Expon. (Subbasins)

Conclusion

A hybrid supervised-unsupervised land cover classification and preliminary analysis has been completed for imagery captured in September 2006 and the results have been reported. This effort can provide information that has proven useful in the past in evaluating watershed, water quality, and fish habitat conditions for basin and salmon conservation planning purposes. The current classification of 2006 land cover permits the analysis of changes or trends in land cover over time in comparison with previous results. This will be undertaken once previous products (1991 and 2001 classified land cover) have been updated to include new methods and techniques that were applied to the 2006 product. It is possible or even likely that a model could be developed of future land cover values, based on trends, that could potentially be used to evaluate future salmonid habitat suitability.

More explicitly, opportunities for future work using the methods and/or results found in this report include:

- Revise previous products to include the use of new techniques found useful in the evaluation of 2006 land cover (this has been completed);
- Develop a comparison of 1991, 2001, and 2006 data to determine whether trends might exist and where they might be relevant (this is ongoing);
- Fit the calculated summary values from 1991, 2001, and 2006 to a linear or exponential growth model to predict future subbasin and riparian summary values in select locations;
- Use geographic information system tools to “grow” future land cover based on locations and pace of growth from 1991 to 2006.

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APPENDIX A

2006 LAND COVER VALUES

Table A-1. September 2006 Subbasin Land Cover (%)

WRIA	SUBBASIN	Mature Evergreen Forest	Medium Evergreen Forest	Deciduous Stands	Shrub / Small Trees	Grass	Bare Ground	Medium Density Development	High Density Development	Alpine rock / talus slope	Open Water	Unknown
3	Skagit Flats South	1	8	7	34	36	8	2	3	0	0	0
4	Sauk River	39	15	7	14	10	0	1	0	10	0	3
5	Boulder River	48	16	6	10	5	0	0	0	13	1	1
5	Church Creek	1	6	10	32	38	5	3	4	0	0	0
5	Deer Creek	34	24	7	27	5	1	0	0	1	0	0
5	French-Segelsen	28	20	9	30	9	0	0	1	2	1	0
5	Gold Basin	35	31	8	20	3	0	0	0	2	1	0
5	Harvey Armstrong Creek	7	16	13	26	29	4	3	2	0	1	0
5	Jim Creek	15	23	12	34	12	2	1	0	0	0	0
5	Lower Canyon Creek	8	21	13	46	9	1	1	0	1	1	0
5	Lower North Fk Stillaguamish	8	19	12	32	23	3	1	1	0	1	0
5	Lower Pilchuck Creek	3	20	13	37	22	2	1	1	0	1	0
5	Lower South Fk Stillaguamish	4	8	20	30	27	3	4	2	0	2	0
5	Lower Stillaguamish	1	4	10	28	38	7	3	6	0	3	0
5	Middle North Fk Stillaguamish	17	23	10	37	10	1	0	1	0	1	0
5	Port Susan Drainages	4	10	24	31	20	2	6	1	1	2	0
5	Portage Creek	1	3	14	29	32	8	8	5	0	1	0
5	Robe Valley	18	25	10	37	4	1	0	0	3	1	0
5	Squire Creek	36	10	10	17	11	0	1	0	12	0	3
5	Stillaguamish Canyon	8	32	12	33	7	4	2	2	0	2	0
5	Upper Canyon Creek	31	29	9	21	5	1	0	0	3	0	0
5	Upper North Fk Stillaguamish	33	24	6	33	4	0	0	0	0	0	0
5	Upper Pilchuck Creek	14	27	10	35	9	2	0	0	0	3	0
5	Upper South Fk Stillaguamish	29	21	10	20	8	0	0	0	10	0	1
7	Allen Creek	1	2	9	18	29	4	29	7	0	1	0
7	Ames Creek	4	12	20	34	26	1	2	0	0	1	0

Table A-1. September 2006 Subbasin Land Cover (%)

7	Bear Creek	3	20	19	40	14	2	1	0	0	1	0
7	Beckler River	31	24	8	26	7	0	0	0	4	0	0
7	Cathcart Drainages	2	5	18	30	28	3	6	3	0	4	0
7	Cherry Creek	5	21	17	42	11	1	1	0	0	1	0
7	Coal Creek_Lower	3	17	15	32	20	5	4	1	0	3	0
7	Coal Creek_Upper	3	18	20	33	16	4	3	2	0	1	0
7	Dubuque Creek	3	11	26	39	16	1	2	0	0	3	0
7	Everett Drainages	1	2	8	11	13	7	26	29	0	3	0
7	Fobes Hill	2	2	9	20	37	5	14	6	0	5	0
7	Foss River	30	16	7	12	7	0	1	0	22	3	3
7	French Creek	1	4	14	29	38	4	6	4	0	0	0
7	Griffin Creek	3	31	11	46	4	5	1	0	0	0	0
7	Harris Creek	4	16	24	35	16	1	2	0	0	1	0
7	Lake Stevens	1	3	17	22	22	3	15	4	0	13	0
7	Little Pilchuck	2	6	23	32	28	3	4	1	0	0	0
7	Lower Mainstem Skykomish	5	20	12	38	17	2	2	2	0	2	0
7	Lower Middle Fork Snoqualmie	14	21	13	39	8	1	1	0	3	1	0
7	Lower North Fork Skykomish	27	20	10	22	9	0	0	0	9	1	0
7	Lower North Fork Snoqualmie	19	28	9	26	8	3	0	0	5	3	0
7	Lower Pilchuck	1	5	18	27	31	3	10	2	0	1	0
7	Lower South Fork Skykomish	24	20	11	26	7	0	0	1	10	2	0
7	Lower South Fork Snoqualmie	9	22	14	32	12	2	4	1	0	1	0
7	Lower Sultan River	17	28	13	26	8	3	1	0	0	2	0
7	Lower Tolt River	7	27	18	39	6	1	1	0	0	1	0
7	Lower Woods Creek	1	3	14	27	36	4	10	4	0	1	0
7	Marshland	1	1	8	24	32	6	19	7	0	2	0
7	May Creek	16	16	14	23	16	2	4	2	4	2	0
7	Middle Pilchuck	5	16	22	35	16	2	3	1	0	2	0
7	Mid-Mainstem Snoqualmie	2	8	17	32	30	2	4	2	0	3	0
7	Miller River	37	11	9	13	11	0	1	0	16	1	1

Table A-1. September 2006 Subbasin Land Cover (%)

7	North Fork Tolt River	14	28	11	32	8	4	0	0	2	0	0
7	Olney Creek	19	36	11	25	5	3	0	0	1	0	0
7	Patterson Creek	1	9	22	42	20	1	3	1	0	0	0
7	Pratt River	33	25	7	18	6	0	0	0	9	1	0
7	Quilceda Creek	1	3	12	28	26	8	12	10	0	0	0
7	Raging River	5	26	14	43	8	2	0	0	0	0	0
7	Rapid River	48	17	6	16	8	0	0	0	4	0	0
7	Snohomish Estuary	2	1	3	27	36	4	4	6	0	17	0
7	Snoqualmie Mouth	2	6	16	35	34	1	2	1	0	2	0
7	South Fork Skykomish	23	20	11	25	10	1	0	0	9	1	0
7	South Fork Tolt River_Ad	17	28	8	29	5	1	0	0	5	7	0
7	South Fork Tolt River_Bd	8	25	14	40	6	4	0	0	2	0	0
7	Sunnyside	1	2	10	21	34	6	14	10	0	2	0
7	Tate Creek	3	32	12	44	7	1	0	0	0	0	0
7	Taylor River	34	14	11	18	10	0	1	0	11	2	0
7	Tokul Creek	4	28	11	51	4	2	0	0	0	0	0
7	Tulalip	2	9	18	45	12	2	3	1	1	7	0
7	Tye River	42	19	7	16	8	0	0	0	6	1	0
7	Upper Mainstem Skykomish	14	24	14	28	8	3	1	2	4	2	0
7	Upper Mainstem Snoqualmie	3	16	13	34	25	2	3	1	0	3	0
7	Upper Middle Fork Snoqualmie	31	13	8	13	10	0	1	0	19	1	2
7	Upper North Fork Skykomish	36	18	8	16	10	0	1	0	10	1	1
7	Upper North Fork Snoqualmie	28	22	10	21	9	1	0	0	7	1	0
7	Upper Pilchuck	16	39	8	30	4	1	0	0	1	0	0
7	Upper South Fork Skykomish	30	28	9	22	5	3	0	0	2	1	0
7	Upper South Fork Snoqualmie	21	24	9	24	11	1	0	0	7	1	0
7	Upper Sultan River	22	20	10	24	9	1	0	0	11	3	0
7	Upper Wallace River	19	26	12	26	10	1	1	0	5	1	0
7	West Fork Woods Creek	2	14	22	41	18	1	2	0	0	0	0
7	Woods Creek	6	23	18	38	10	2	1	0	0	2	0

Table A-1. September 2006 Subbasin Land Cover (%)

8	Bear Creek	6	10	19	25	23	2	9	4	0	1	0
8	Little Bear Creek	4	6	18	22	22	4	14	9	0	0	0
8	Lyon Creek	4	5	11	12	22	1	34	7	0	0	0
8	McAleer Creek	3	3	7	8	19	2	31	22	0	2	0
8	North Creek	2	3	10	15	20	4	28	16	0	1	0
8	Puget Sound Drainage	4	6	11	12	24	3	26	12	0	1	0
8	Swamp Creek	2	2	8	15	18	4	29	20	0	0	0

Table A-2. September 2006 Calculated Subbasin Summary Land Cover Parameters (%)

WRIA	SUBBASIN	Adjusted Total Forest	Adjusted Total Mature Evergreen Forest	Adjusted Total Impervious Area
3	Skagit Flats South	13	1	3.60
4	Sauk River	66	45	0.48
5	Boulder River	79	56	0.00
5	Church Creek	13	1	4.95
5	Deer Creek	62	34	0.00
5	French-Segelsen	55	29	0.91
5	Gold Basin	73	36	0.00
5	Harvey Armstrong Creek	30	7	3.12
5	Jim Creek	45	15	0.45
5	Lower Canyon Creek	37	8	0.45
5	Lower North Fk Stillaguamish	34	8	1.34
5	Lower Pilchuck Creek	30	3	1.34
5	Lower South Fk Stillaguamish	23	4	3.53
5	Lower Stillaguamish	11	1	6.55
5	Middle North Fk Stillaguamish	46	17	0.89
5	Port Susan Drainages	28	4	3.56
5	Portage Creek	12	1	8.02
5	Robe Valley	51	19	0.00
5	Squire Creek	61	42	0.49
5	Stillaguamish Canyon	48	8	2.65
5	Upper Canyon Creek	67	32	0.00
5	Upper North Fk Stillaguamish	60	33	0.00
5	Upper Pilchuck Creek	48	14	0.00
5	Upper South Fk Stillaguamish	62	33	0.00

Table A-2. September 2006 Calculated Subbasin Summary Land Cover Parameters (%)

WRIA	SUBBASIN	Adjusted Total Forest	Adjusted Total Mature Evergreen Forest	Adjusted Total Impervious Area
7	Allen Creek	8	1	19.16
7	Ames Creek	27	4	0.89
7	Bear Creek	34	3	0.45
7	Beckler River	62	32	0.00
7	Cathcart Drainages	18	2	5.19
7	Cherry Creek	36	5	0.45
7	Coal Creek_Lower	29	3	2.62
7	Coal Creek_Upper	32	3	3.12
7	Dubuque Creek	29	3	0.87
7	Everett Drainages	8	1	36.70
7	Fobes Hill	9	2	11.14
7	Foss River	69	42	0.54
7	French Creek	13	1	6.30
7	Griffin Creek	40	3	0.45
7	Harris Creek	34	4	0.89
7	Lake Stevens	15	1	9.16
7	Little Pilchuck	21	2	2.70
7	Lower Mainstem Skykomish	32	5	2.65
7	Lower Middle Fork Snoqualmie	44	15	0.46
7	Lower North Fork Skykomish	58	30	0.00
7	Lower North Fork Snoqualmie	56	21	0.00
7	Lower Pilchuck	16	1	6.24
7	Lower South Fork Skykomish	57	27	0.98
7	Lower South Fork Snoqualmie	39	9	2.67
7	Lower Sultan River	53	17	0.44
7	Lower Tolt River	44	7	0.45
7	Lower Woods Creek	12	1	8.02
7	Marshland	7	1	14.56
7	May Creek	42	17	3.67
7	Middle Pilchuck	34	5	2.21
7	Mid-Mainstem Snoqualmie	20	2	3.50
7	Miller River	65	45	0.52
7	North Fork Tolt River	49	14	0.00
7	Olney Creek	62	19	0.00
7	Patterson Creek	22	1	2.25
7	Pratt River	69	37	0.00
7	Quilceda Creek	11	1	14.40
7	Raging River	39	5	0.00
7	Rapid River	71	50	0.00
7	Snohomish Estuary	6	2	6.15
7	Snoqualmie Mouth	17	2	1.76
7	South Fork Skykomish	55	26	0.00
7	South Fork Tolt River_Ad	56	19	0.00
7	South Fork Tolt River_Bd	42	8	0.00
7	Sunnyside	9	1	15.00
7	Tate Creek	42	3	0.00
7	Taylor River	62	39	0.49
7	Tokul Creek	38	4	0.00
7	Tulalip	23	2	2.12

Table A-2. September 2006 Calculated Subbasin Summary Land Cover Parameters (%)

WRIA	SUBBASIN	Adjusted Total Forest	Adjusted Total Mature Evergreen Forest	Adjusted Total Impervious Area
7	Tye River	70	45	0.00
7	Upper Mainstem Skykomish	49	15	2.30
7	Upper Mainstem Snoqualmie	27	3	2.18
7	Upper Middle Fork Snoqualmie	62	40	0.54
7	Upper North Fork Skykomish	66	41	0.49
7	Upper North Fork Snoqualmie	60	30	0.00
7	Upper Pilchuck	60	16	0.00
7	Upper South Fork Skykomish	65	31	0.00
7	Upper South Fork Snoqualmie	54	23	0.00
7	Upper Sultan River	55	26	0.00
7	Upper Wallace River	55	20	0.47
7	West Fork Woods Creek	28	2	0.90
7	Woods Creek	40	6	0.44
8	Bear Creek	27	6	7.57
8	Little Bear Creek	20	4	14.40
8	Lyon Creek	15	4	21.60
8	McAleer Creek	10	3	33.09
8	North Creek	11	2	26.73
8	Puget Sound Drainage	16	4	22.28
8	Swamp Creek	8	2	31.05

Table A-3. September 2006 Nearstream Land Cover (%)

WRIA	SUBBASIN	Mature Evergreen Forest	Medium Evergreen Forest	Deciduous Stands	Shrub / Small Trees	Grass	Bare Ground	Medium Density Development	High Density Development	Alpine rock / talus slope	Open Water	Unknown
3	Skagit Flats South	1	5	9	37	38	5	2	2	0	0	0
4	Sauk River	23	16	14	25	10	4	1	5	2	0	0
5	Boulder River	38	14	13	16	5	0	1	0	11	1	0
5	Church Creek	1	5	13	35	38	3	3	2	0	0	0
5	Deer Creek	34	21	11	26	5	2	0	1	0	0	0
5	French-Segelsen	15	12	13	43	13	0	1	2	0	0	0
5	Gold Basin	43	22	10	15	4	2	0	0	2	1	0
5	Harvey Armstrong Creek	5	15	16	29	29	3	3	1	0	1	0
5	Jim Creek	13	17	20	35	12	1	1	0	0	1	0
5	Lower Canyon Creek	11	20	21	38	8	1	1	0	0	0	0
5	Lower North Fk Stillaguamish	6	13	14	35	26	2	1	3	0	0	0
5	Lower Pilchuck Creek	3	15	19	38	21	1	1	1	0	0	0
5	Lower South Fk Stillaguamish	7	7	22	27	24	1	4	6	0	1	0
5	Lower Stillaguamish	3	4	9	27	38	5	4	8	0	1	0
5	Middle North Fk Stillaguamish	11	14	14	42	13	1	1	3	0	0	0
5	Port Susan Drainages	12	11	19	19	15	1	7	8	5	3	0
5	Portage Creek	1	4	16	26	33	5	8	5	0	0	0
5	Robe Valley	20	21	18	31	5	4	0	0	0	1	0
5	Squire Creek	19	14	18	37	11	1	0	0	0	0	0
5	Stillaguamish Canyon	23	23	16	25	7	2	1	2	0	1	0
5	Upper Canyon Creek	32	26	14	20	6	1	0	0	1	0	0
5	Upper North Fk Stillaguamish	35	25	11	25	4	0	0	0	0	0	0
5	Upper Pilchuck Creek	14	24	17	37	6	1	0	0	1	1	0
5	Upper South Fk Stillaguamish	32	26	12	22	5	2	0	0	1	0	0
7	Allen Creek	1	2	8	18	41	3	19	6	0	2	0
7	Ames Creek	4	7	18	26	41	1	1	1	0	1	0

Table A-3. September 2006 Nearstream Land Cover (%)

WRIA	SUBBASIN	Mature Evergreen Forest	Medium Evergreen Forest	Deciduous Stands	Shrub / Small Trees	Grass	Bare Ground	Medium Density Development	High Density Development	Alpine rock / talus slope	Open Water	Unknown
7	Bear Creek	4	19	30	37	8	0	1	0	0	1	0
7	Beckler River	27	18	13	31	6	1	0	0	3	1	0
7	Cathcart Drainages	3	4	16	32	32	2	3	3	1	4	0
7	Cherry Creek	7	19	19	38	14	1	1	0	0	1	0
7	Coal Creek_Lower	6	16	15	32	22	1	3	2	0	2	0
7	Coal Creek_Upper	4	10	27	31	17	2	4	3	0	1	0
7	Dubuque Creek	3	11	28	35	17	1	3	1	0	1	0
7	Everett Drainages	6	4	12	13	10	10	11	30	0	4	0
7	Fobes Hill	8	1	6	15	25	3	13	9	1	19	0
7	Foss River	43	9	12	13	4	0	0	0	17	3	0
7	French Creek	2	6	16	27	41	2	3	2	0	1	0
7	Griffin Creek	7	27	18	40	6	2	1	0	0	0	0
7	Harris Creek	6	15	24	33	17	1	2	1	0	1	0
7	Lake Stevens	3	3	18	26	22	1	18	6	0	4	0
7	Little Pilchuck	2	5	23	35	28	2	4	1	0	0	0
7	Lower Mainstem Skykomish	7	12	17	31	22	3	2	5	0	2	0
7	Lower Middle Fork Snoqualmie	13	18	20	32	9	2	1	2	1	1	0
7	Lower North Fork Skykomish	22	19	15	25	7	3	0	2	4	1	0
7	Lower North Fork Snoqualmie	18	27	13	23	6	5	1	0	5	2	0
7	Lower Pilchuck	3	6	20	27	33	2	7	2	0	0	0
7	Lower South Fork Skykomish	22	19	16	24	5	2	0	3	6	2	0
7	Lower South Fork Snoqualmie	7	11	25	33	16	1	4	2	0	0	0
7	Lower Sultan River	24	20	18	25	8	1	1	1	2	1	0
7	Lower Tolt River	12	18	26	34	7	0	1	1	0	1	0
7	Lower Woods Creek	2	5	21	27	33	4	6	2	0	1	0
7	Marshland	2	1	6	23	38	15	6	6	0	3	0

Table A-3. September 2006 Nearstream Land Cover (%)

WRIA	SUBBASIN	Mature Evergreen Forest	Medium Evergreen Forest	Deciduous Stands	Shrub / Small Trees	Grass	Bare Ground	Medium Density Development	High Density Development	Alpine rock / talus slope	Open Water	Unknown
7	May Creek	12	10	19	25	18	2	6	4	3	2	0
7	Middle Pilchuck	7	13	28	29	18	1	3	1	0	1	0
7	Mid-Mainstem Snoqualmie	6	6	14	28	37	2	2	4	0	2	0
7	Miller River	36	14	12	18	8	1	0	0	10	1	0
7	North Fork Tolt River	18	31	12	28	6	4	0	0	1	0	0
7	Olney Creek	21	22	20	26	7	2	1	0	1	0	0
7	Patterson Creek	2	10	24	36	26	1	1	0	0	0	0
7	Pratt River	34	22	9	19	3	0	0	0	9	4	0
7	Quilceda Creek	1	4	16	25	31	4	13	5	0	0	0
7	Raging River	7	22	18	44	6	1	1	0	0	1	0
7	Snohomish Estuary	5	1	6	17	29	6	11	14	0	11	0
7	Snoqualmie Mouth	6	4	12	27	40	2	2	4	0	3	0
7	South Fork Skykomish	17	17	17	33	7	4	0	0	3	1	0
7	South Fork Tolt River_Ad	12	40	9	21	5	4	0	0	3	6	0
7	South Fork Tolt River_Bd	10	22	22	36	6	4	1	0	0	0	0
7	Sunnyside	7	2	8	23	39	2	5	7	0	8	0
7	Tate Creek	3	27	19	38	11	1	0	0	0	0	0
7	Taylor River	38	16	11	19	6	0	0	0	8	1	0
7	Tokul Creek	7	27	15	44	5	1	0	0	0	1	0
7	Tulalip	5	8	18	36	12	1	4	5	4	4	0
7	Tye River	40	21	9	20	6	1	0	0	2	0	0
7	Upper Mainstem Skykomish	10	15	21	31	8	2	2	7	1	2	0
7	Upper Mainstem Snoqualmie	5	6	11	29	38	3	3	3	0	2	0
7	Upper Middle Fork Snoqualmie	37	17	11	16	5	1	0	0	10	2	0
7	Upper North Fork Skykomish	27	20	12	23	10	2	1	0	6	0	0
7	Upper North Fork Snoqualmie	28	24	12	22	6	1	0	0	5	2	0

Table A-3. September 2006 Nearstream Land Cover (%)

WRIA	SUBBASIN	Mature Evergreen Forest	Medium Evergreen Forest	Deciduous Stands	Shrub / Small Trees	Grass	Bare Ground	Medium Density Development	High Density Development	Alpine rock / talus slope	Open Water	Unknown
7	Upper Pilchuck	20	34	15	26	4	0	0	0	0	0	0
7	Upper South Fork Skykomish	27	14	17	24	8	8	1	0	1	0	0
7	Upper South Fork Snoqualmie	27	25	12	21	7	2	0	0	4	1	0
7	Upper Sultan River	18	23	13	28	8	4	0	0	3	1	0
7	Upper Wallace River	26	26	15	25	5	0	1	0	1	1	0
7	West Fork Woods Creek	3	11	26	37	21	1	1	0	0	0	0
7	Woods Creek	7	18	26	33	13	1	1	0	0	1	0
8	Bear Creek	6	8	21	26	22	2	7	4	0	2	0
8	Little Bear Creek	4	6	21	27	20	4	9	9	0	0	0
8	Lyon Creek	11	10	18	16	24	0	14	1	0	1	0
8	McAleer Creek	4	6	12	16	21	2	20	14	0	3	0
8	North Creek	2	4	16	23	22	3	17	13	0	1	0
8	Puget Sound Drainage	10	9	18	16	16	1	12	12	1	6	0
8	Swamp Creek	3	4	14	26	17	2	23	11	0	1	0

Table A-4. September 2006 Calculated Nearstream Summary Parameters (%)

WRIA	SUBBASIN	Adjusted Total Forest Cover	Adjusted Mature Evergreen Forest	Adjusted Total Impervious Area
3	Skagit Flats South	11	1	2.70
4	Sauk River	48	23	5.05
5	Boulder River	67	43	0.51
5	Church Creek	13	1	3.15
5	Deer Creek	61	34	0.90
5	French-Segelsen	34	15	2.25
5	Gold Basin	73	44	0.00
5	Harvey Armstrong Creek	29	5	2.27
5	Jim Creek	41	13	0.45
5	Lower Canyon Creek	43	11	0.45
5	Lower North Fk Stillaguamish	27	6	3.15
5	Lower Pilchuck Creek	28	3	1.35
5	Lower South Fk Stillaguamish	26	7	7.27
5	Lower Stillaguamish	12	3	9.09
5	Middle North Fk Stillaguamish	33	11	3.15
5	Port Susan Drainages	36	13	11.25
5	Portage Creek	14	1	8.10
5	Robe Valley	51	20	0.00
5	Squire Creek	43	19	0.00
5	Stillaguamish Canyon	55	23	2.27
5	Upper Canyon Creek	66	32	0.00
5	Upper North Fk Stillaguamish	66	35	0.00
5	Upper Pilchuck Creek	48	14	0.00
5	Upper South Fk Stillaguamish	65	32	0.00

Table A-4. September 2006 Calculated Nearstream Summary Parameters (%)

WRIA	SUBBASIN	Adjusted Total Forest Cover	Adjusted Mature Evergreen Forest	Adjusted Total Impervious Area
7	Allen Creek	8	1	14.23
7	Ames Creek	21	4	1.36
7	Bear Creek	40	4	0.45
7	Beckler River	54	28	0.00
7	Cathcart Drainages	17	3	4.26
7	Cherry Creek	37	7	0.45
7	Coal Creek_Lower	31	6	3.21
7	Coal Creek_Upper	29	4	4.55
7	Dubuque Creek	30	3	2.27
7	Everett Drainages	17	6	33.28
7	Fobes Hill	15	10	17.44
7	Foss River	73	54	0.00
7	French Creek	17	2	3.18
7	Griffin Creek	44	7	0.45
7	Harris Creek	35	6	1.82
7	Lake Stevens	17	3	14.06
7	Little Pilchuck	20	2	2.70
7	Lower Mainstem Skykomish	29	7	5.51
7	Lower Middle Fork Snoqualmie	43	13	2.30
7	Lower North Fork Skykomish	52	23	1.89
7	Lower North Fork Snoqualmie	56	19	0.48
7	Lower Pilchuck	20	3	4.95
7	Lower South Fork Skykomish	54	24	2.93
7	Lower South Fork Snoqualmie	32	7	3.60
7	Lower Sultan River	56	25	1.39
7	Lower Tolt River	45	12	1.36
7	Lower Woods Creek	19	2	4.55
7	Marshland	6	2	8.35
7	May Creek	34	13	6.63
7	Middle Pilchuck	36	7	2.27
7	Mid-Mainstem Snoqualmie	20	6	4.59
7	Miller River	64	40	0.00
7	North Fork Tolt River	56	18	0.00
7	Olney Creek	55	21	0.45
7	Patterson Creek	25	2	0.45
7	Pratt River	70	39	0.00
7	Quilceda Creek	14	1	10.35
7	Raging River	39	7	0.45
7	Snohomish Estuary	10	6	19.72

Table A-4. September 2006 Calculated Nearstream Summary Parameters (%)

WRIA	SUBBASIN	Adjusted Total Forest Cover	Adjusted Mature Evergreen Forest	Adjusted Total Impervious Area
7	Snoqualmie Mouth	17	6	4.64
7	South Fork Skykomish	45	18	0.00
7	South Fork Tolt River_Ad	63	13	0.00
7	South Fork Tolt River_Bd	44	10	0.45
7	Sunnyside	15	8	9.29
7	Tate Creek	40	3	0.00
7	Taylor River	66	42	0.00
7	Tokul Creek	43	7	0.00
7	Tulalip	25	5	6.85
7	Tye River	67	41	0.00
7	Upper Mainstem Skykomish	38	10	7.42
7	Upper Mainstem Snoqualmie	17	5	4.13
7	Upper Middle Fork Snoqualmie	68	42	0.00
7	Upper North Fork Skykomish	57	29	0.48
7	Upper North Fork Snoqualmie	63	30	0.00
7	Upper Pilchuck	62	20	0.00
7	Upper South Fork Skykomish	51	27	0.45
7	Upper South Fork Snoqualmie	62	28	0.00
7	Upper Sultan River	50	19	0.00
7	Upper Wallace River	61	27	0.46
7	West Fork Woods Creek	28	3	0.45
7	Woods Creek	40	7	0.45
8	Bear Creek	26	6	6.89
8	Little Bear Creek	22	4	12.15
8	Lyon Creek	31	11	7.27
8	McAleer Creek	17	4	22.27
8	North Creek	15	2	19.55
8	Puget Sound Drainage	31	11	17.42
8	Swamp Creek	15	3	20.45

Table A-5 Land Cover within Broad Land Use Categories

Future Land Use\Land Cover Class	MatEVGF	MedEVGF	Decid	Shrub	Grass	BareG	MDD	HDD	Alpine	OW	Unk
Ag	1	1	7	24	48	6	3	4	0	6	0
Forest-Fed	38	18	7	15	8	0	0	0	10	0	2
Forest-Private	10	26	12	40	7	2	0	0	1	1	0
Forest-State	17	29	11	32	6	2	0	0	3	0	0
Rural	3	8	20	35	25	3	4	2	0	1	0
UGA/City	2	2	8	14	20	6	26	19	0	2	0
UGA/Unincorporated	2	3	11	17	21	6	25	12	0	3	0

Table A-5 Land Cover within Broad Land Use Categories

Adj MEF	AdjTF	ADjTIA	Acres	mef	tf	s&st	imperv
1.1	6.2	5.3					
43.2	68.0	0.0	628645				
10.2	43.5	0.0	110501				
17.5	53.7	0.0	155721				
3.0	22.2	3.6					
2.0	8.6	29.4	76122				
2.1	11.4	22.7	43843				